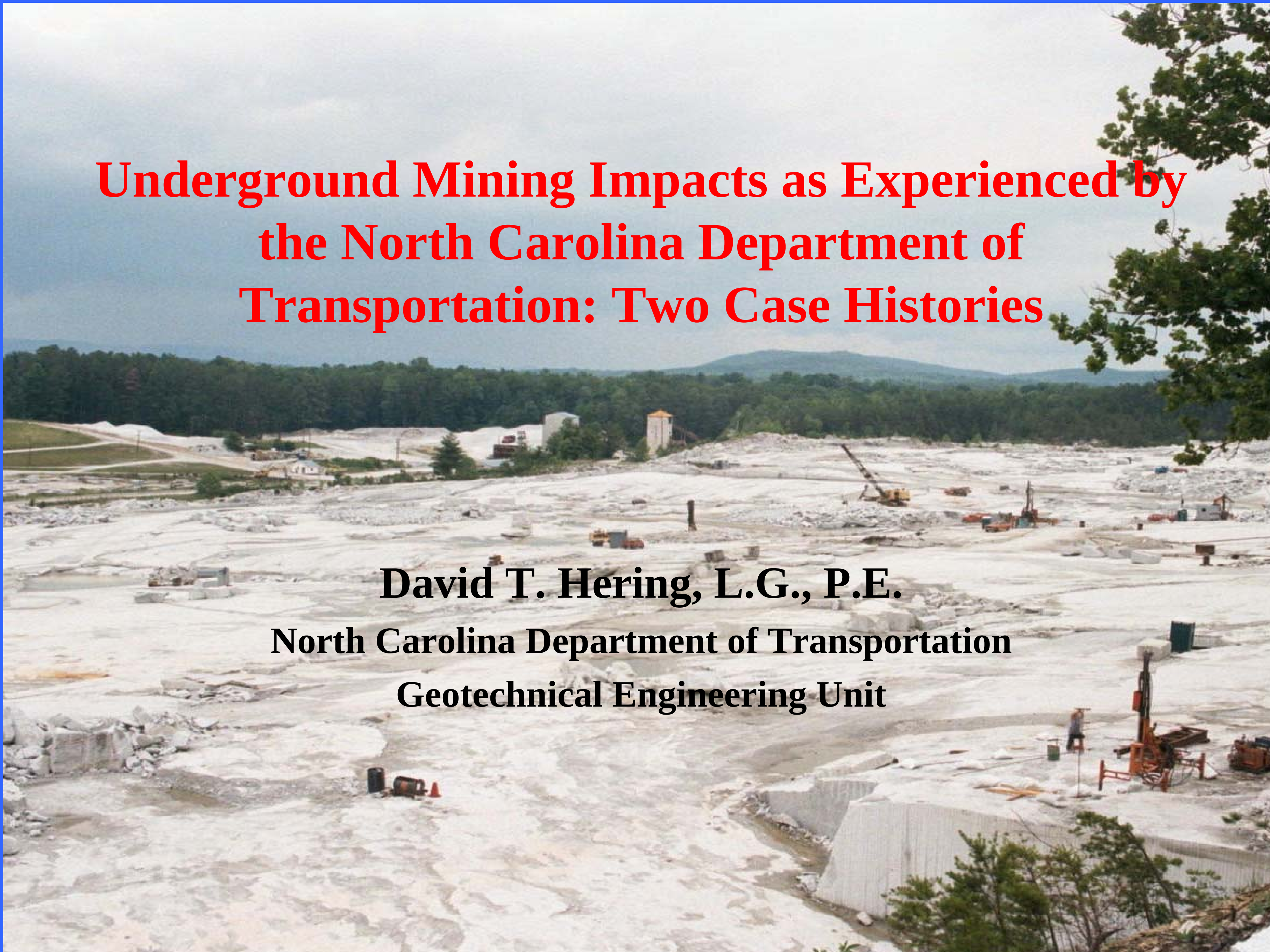
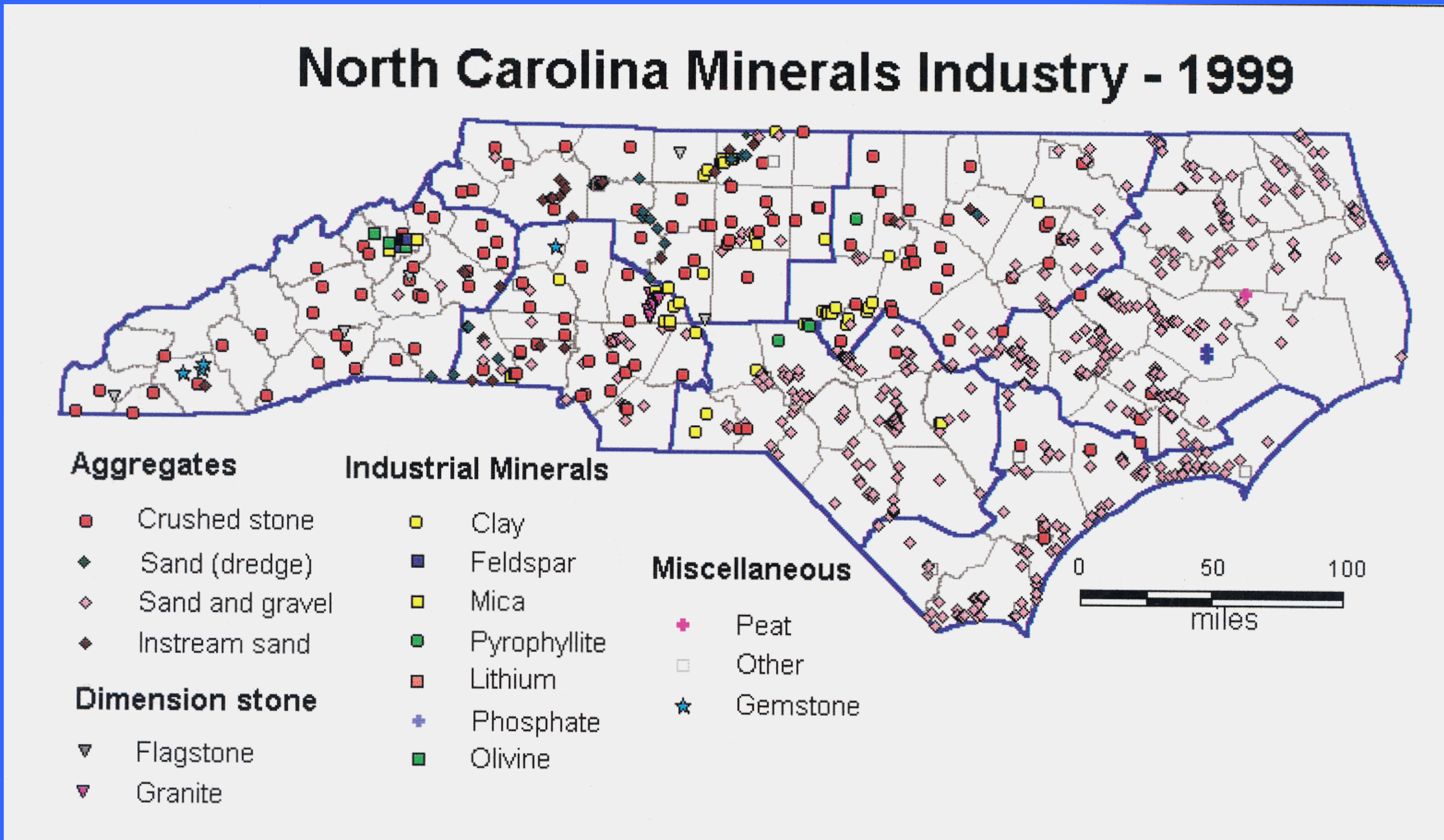


Underground Mining Impacts as Experienced by the North Carolina Department of Transportation: Two Case Histories

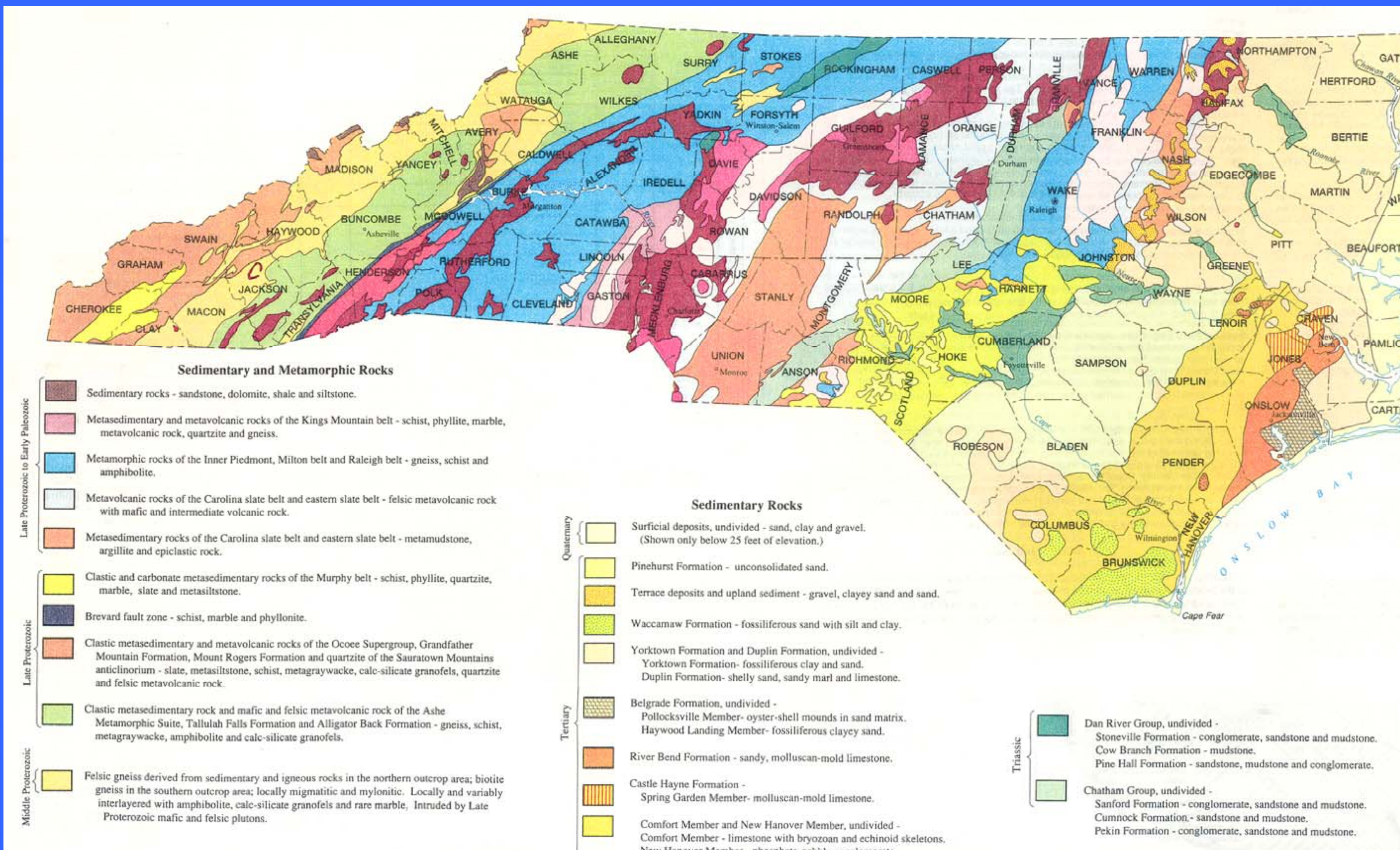
David T. Hering, L.G., P.E.

North Carolina Department of Transportation

Geotechnical Engineering Unit


North Carolina Minerals Industry - 1999
Aggregates
Crushed stone
Sand (dredge)
Sand and gravel
Instream sand
Dimension stone
Flagstone
Granite
Industrial Minerals
Clay
Feldspar
Mica
Pyrophyllite
Lithium
Phosphate
Olivine
Miscellaneous
Peat
Other
Gemstone
0
50
100
miles

Generalized Geologic Map of North Carolina



Physiography

North Carolina can be divided into three physiographic provinces, the Coastal Plain, the Piedmont and the Blue Ridge. Each province is characterized by particular types of landforms.

The Coastal Plain is characterized by flat land to gently rolling hills and valleys. Elevations range from sea level near the coast to about 600 feet in the Sand Hills of the southern Inner Coastal Plain.

The Piedmont Province lies between the Coastal Plain and the Blue Ridge Mountains. The Piedmont occupies about 45 percent of the area of the state. Along the border between the Piedmont and the Coastal Plain, elevations range from 300 to 600 feet above sea level. To the west, elevations gradually rise to about 1,500 feet above sea level at the foot of the Blue Ridge. The Piedmont is characterized by gently rolling, well rounded hills and long low ridges with a few hundred feet of elevation difference between the hills and valleys. The Piedmont includes some relatively low mountains including the South Mountains and the Uwharrie Mountains.

The Blue Ridge is a deeply dissected mountainous area of numerous steep mountain ridges, intermontane basins and trench valleys that intersect at all angles and give the area its rugged mountain character. The Blue Ridge contains the highest elevations and the most rugged topography in the Appalachian Mountain system of eastern North America. The North Carolina portion of the Blue Ridge is about 200 hundred miles long and ranges from 15 to 55 miles wide. It contains an area of about 6,000 square miles, or about 10 percent of the area of the state.

Within North Carolina, 43 peaks exceed 6,000 feet in elevation and 82 peaks are between 5,000 and 6,000 feet. On the west, the Great Smoky Mountains is the dominant range with several peaks that reach more than 6000 feet. On the eastern side of the North Carolina Blue Ridge, the highest range is the Black Mountains which extend for some 15 miles and contain a dozen peaks that exceed 6,000 feet in elevation. This group includes Mount Mitchell. At an elevation of 6,684 feet, it is the highest peak of eastern North America. Other prominent ranges from northeast to southwest are the Pisgah Mountains, Newfound Mountains, Balsam Mountains, Cowee Mountains, Nantahala Mountains, Snowbird Mountains and the Valley River Mountains.

Geology

Three major classes of rocks common to North Carolina are igneous, metamorphic and sedimentary. North Carolina has a long and complex geologic history. Although much remains to be learned, detailed geologic studies provide a general understanding of regional geological relationships. The state is best described in terms of geological belts; that is, areas with similar rock types and geologic history.

Blue Ridge Belt: This mountainous region is composed of rocks from over one billion to about one-half billion years old. This complex mixture of igneous, sedimentary and metamorphic rock has repeatedly been squeezed, fractured, faulted and twisted into folds. The Blue Ridge belt is well known for its deposits of feldspar, mica and quartz–basic materials used in the ceramic, paint and electronic industries. Olivine is mined for use as refractory material and foundry molding sand.

Inner Piedmont Belt: The Inner Piedmont belt is the most intensely deformed and metamorphosed segment of the Piedmont. The metamorphic rocks range from 500 to 750 million years in age. They include gneiss and schist that have been intruded by younger granitic rocks. The northeast-trending Brevard fault zone forms much of the boundary between the Blue Ridge and Inner Piedmont belts. Although this zone of strongly deformed rocks is one of the major structural features in the southern Appalachians, its origin is poorly understood. Crushed stone for road aggregate and building construction is the principal commodity produced.

Kings Mountain Belt: The belt consists of moderately deformed and metamorphosed volcanic and sedimentary rocks. The rocks are about 400-500 million yearls old. Lithium deposits here provide raw materials for chemical compounds, ceramics, glass, greases, batteries and TV glass.

Milton Belt: This belt consists of gneiss, schist and metamorphosed intrusive rocks. The principal mineral resource is crushed stone for road aggregate and for building construction.

Charlotte Belt: The belt consists mostly of igneous rocks such as granite, diorite and gabbro. These are 300-500 million years old. The igneous rocks are good sources for crushed and dimension stone for road aggregate and buildings.

Carolina Slate Belt: This belt consists of heated and deformed volcanic and sedimentary rocks. It was the site of a series of oceanic volcanic islands about 550-650 million years ago. This belt is known for its numerous abandoned gold mines and prospects. North Carolina led the nation in gold production before the California Gold Rush of 1849. In recent decades, only minor gold mining has taken place, but mining companies continue to show interest in the area. Mineral production is crushed stone for road aggregate and pyrophyllite for refractories, ceramics, filler, paint and insecticide carriers.

Triassic Basins: The basins are filled with sedimentary rocks that formed about 200-190 million years ago. Streams carried mud, silt, sand and gravel from adjacent highlands into rift valleys similar to those of Africa today. The mudstones are mined and processed to make brick, sewer pipe, structural tile and drain tile.

Raleigh Belt: The Raleigh belt contains granite, gneiss and schist. In the 19th century, there were a number of small building stone quarries in this region, but today the main mineral product is crushed stone for construction and road aggregate.

Eastern Slate Belt: This belt contains slightly metamorphosed volcanic and sedimentary rocks similar to those of the Carolina slate belt. The rocks are poorly exposed and partially covered by Coastal Plain sediments. The metamorphic rocks, 500-600 million years old, are intruded by younger, approximately 300 million year old, granitic bodies. Gold was once mined in the belt, and small occurrences of molybdenite, an ore of molybdenum, have been prospected here. Crushed stone, clay, sand and gravel are currently mined in this belt.

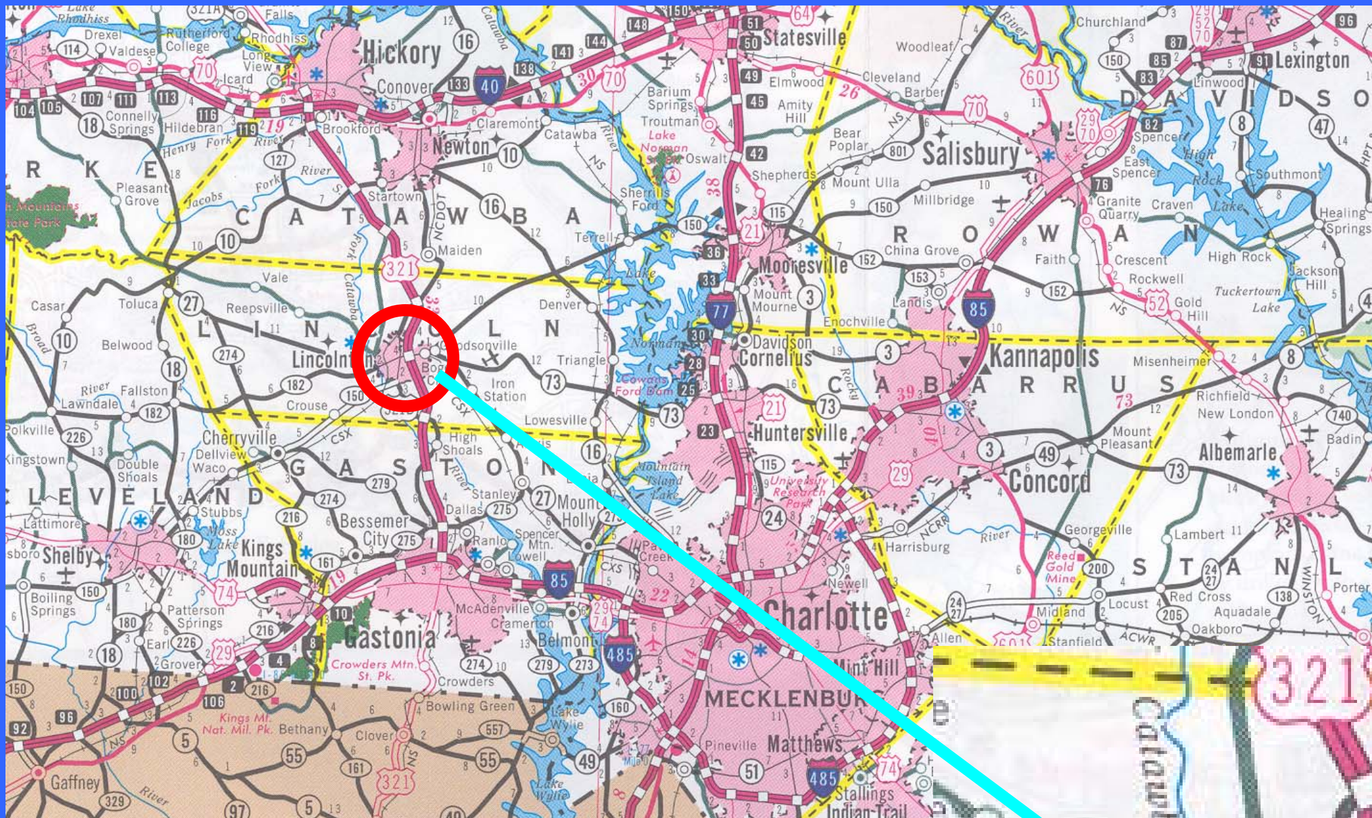
Coastal Plain: The Coastal Plain is a wedge of mostly marine sedimentary rocks that gradually thickens to the east. The Coastal Plain is the largest geologic belt in the state, covering about 45 percent of the land area. The most common sediment types are sand and clay, although a significant amount of limestone occurs in the southern part of the Coastal Plain. In the Coastal Plain, geology is best understood from studying data gathered from well drilling. The state's most important mineral resource in terms of dollar value is phosphate, an important fertilizer component, mined near Aurora, Beaufort County. Industrial sand for making container and flat glass and ferrosilicon and used for filtration and sandblasting is mined in the Sand Hills area.

Mineral Industry

North Carolina has important deposits of many minerals and annually leads the nation in the production of feldspar, lithium minerals, scrap mica, olivine and pyrophyllite. The state ranks second in phosphate rock production and ranks in the top five in clay and crushed granite production. North Carolina does not produce significant quantities of metallic minerals.

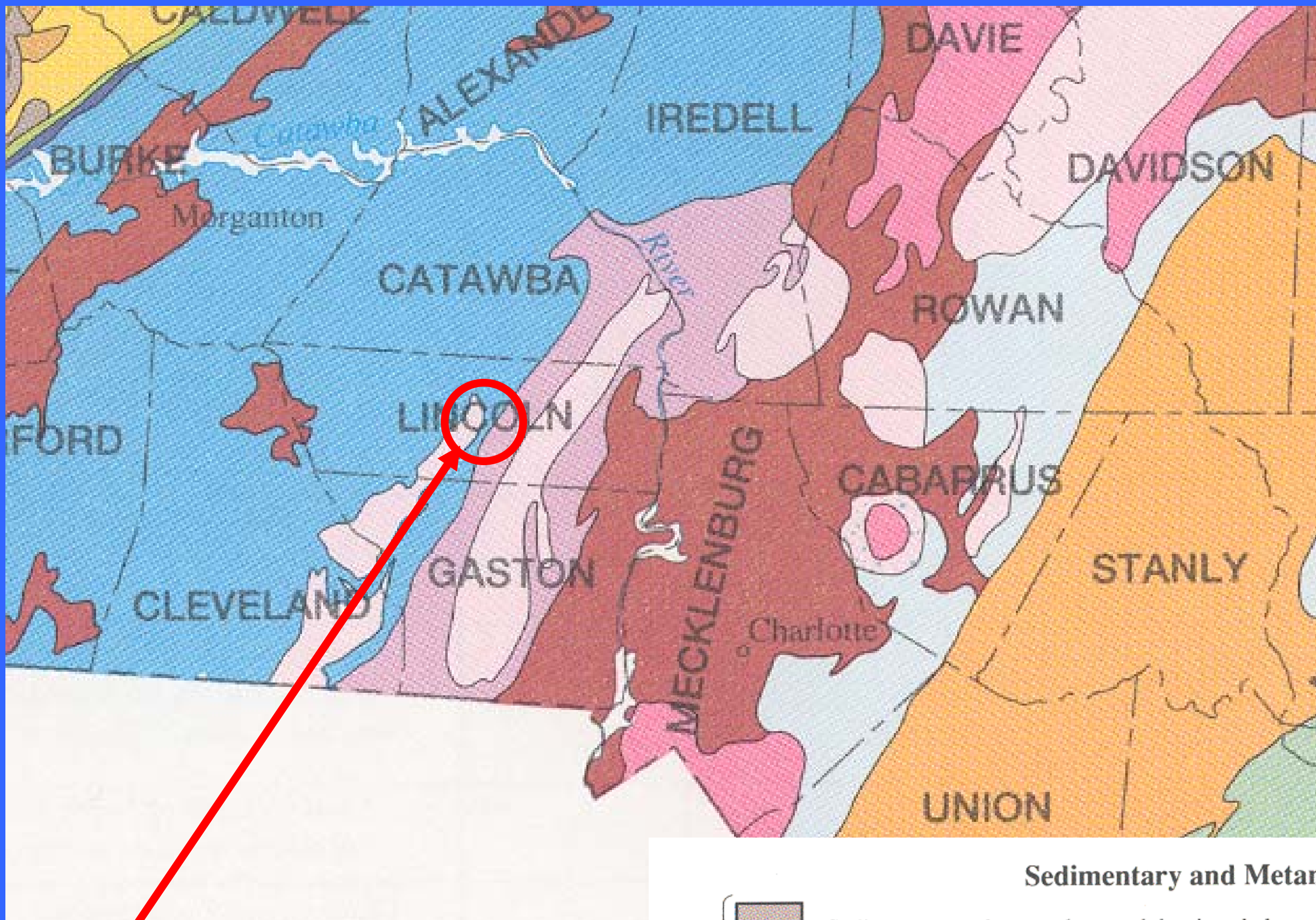
R-0617C, Lincoln Co., NC

Site 1, Tin Mine


Hickory
Conover
Newton
Statesville
Salisbury
Lexington
Mooresville
Kannapolis
Concord
Albemarle
Lincolnton
Cherryville
Shelby
Kings Mountain
Gastonia
Charlotte
Huntersville
Davidson
Cornelius
Matthews
Mint Hill
MECKLENBURG
Gaffney
Stallings
Indian Trail
Belmont
Mount Holly
Bessemer City
Denver
Maiden
Catawba
Lincolnton


321
Catawba
Lincolnton
Goodsonville
Boger City
Iron Station
Crouse
182
150
321B
CSX
High Shoals
Alexis

Site 1



Site 1

Sedimentary and Metamorphic Rocks

Late Proterozoic to Early Paleozoic

- Sedimentary rocks - sandstone, dolomite, shale and siltstone.
- Metasedimentary and metavolcanic rocks of the Kings Mountain belt - schist, phyllite, marble, metavolcanic rock, quartzite and gneiss.
- Metamorphic rocks of the Inner Piedmont, Milton belt and Raleigh belt - gneiss, schist and amphibolite.
- Metavolcanic rocks of the Carolina slate belt and eastern slate belt - felsic metavolcanic rock with mafic and intermediate volcanic rock.
- Metasedimentary rocks of the Carolina slate belt and eastern slate belt - metamudstone, argillite and epiclastic rock.

Cassiterite first discovered in North Carolina in 1883 near King’s Mountain. Mined periodically from 1885 until the 1940’s

Cassiterite occurs in both pegmatite's and greissens within the Kings Mountain Belt

The highest concentrations of cassiterite are typically within a few feet of the contact between the pegmatite and greissen

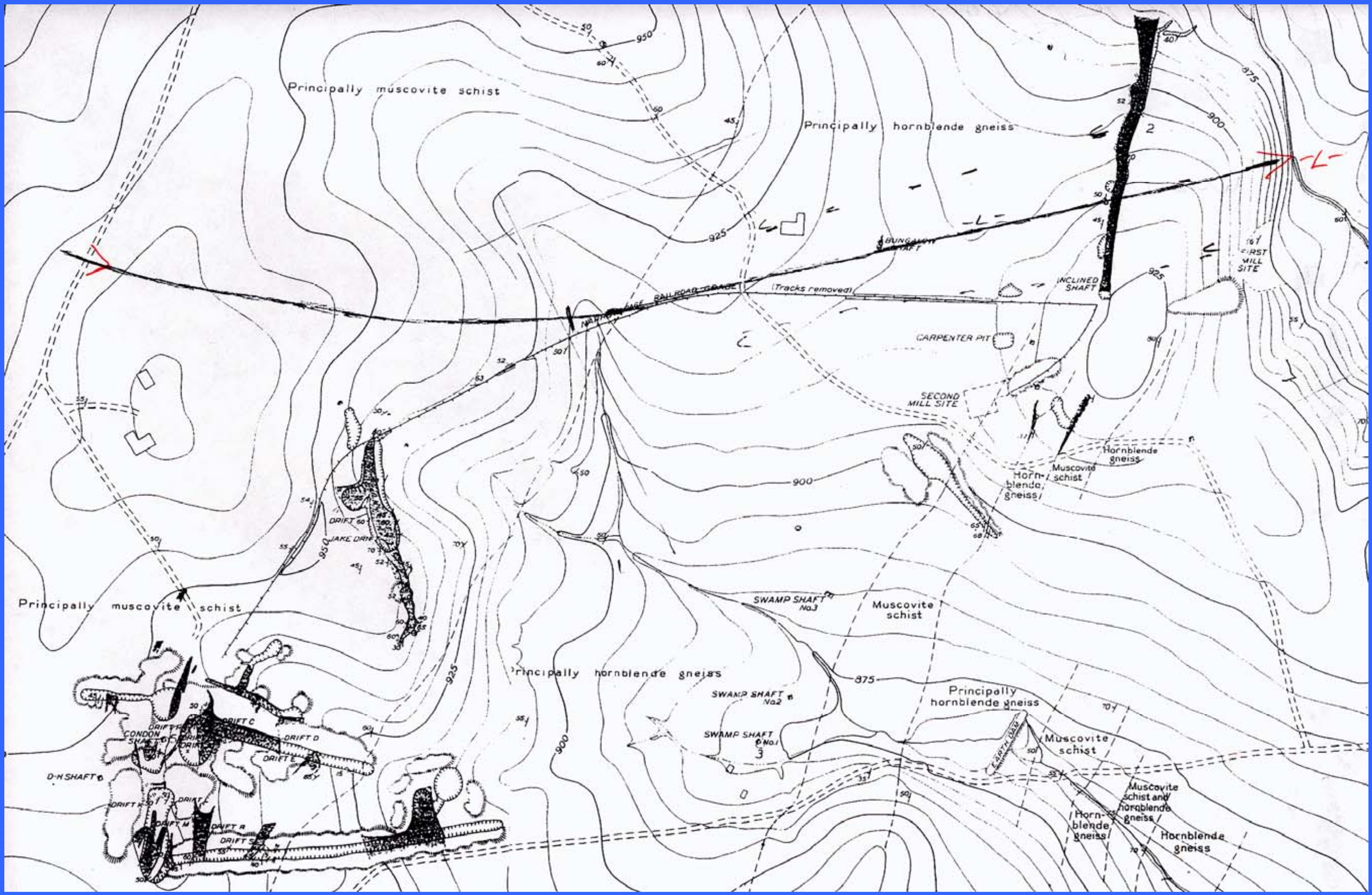
The pegmatite is associated with intrusions of Cherryville Granite

NCDOT first became aware of mine workings from property owner during site reconnaissance

Search of available literature uncovered information on the immediate site and the overall region mined

Borings performed in 1999 did not encounter any mine shafts or tunnels

Geophysical investigation performed in May 2000

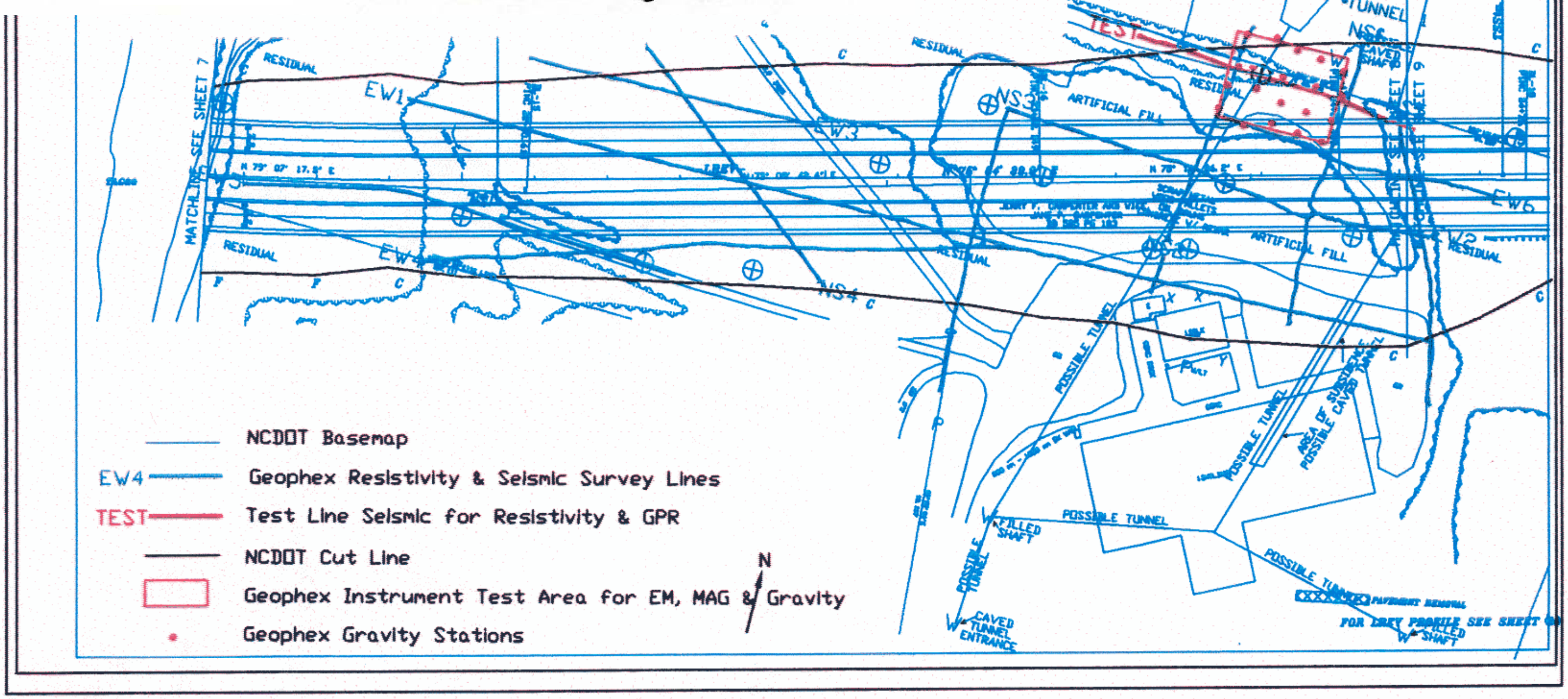


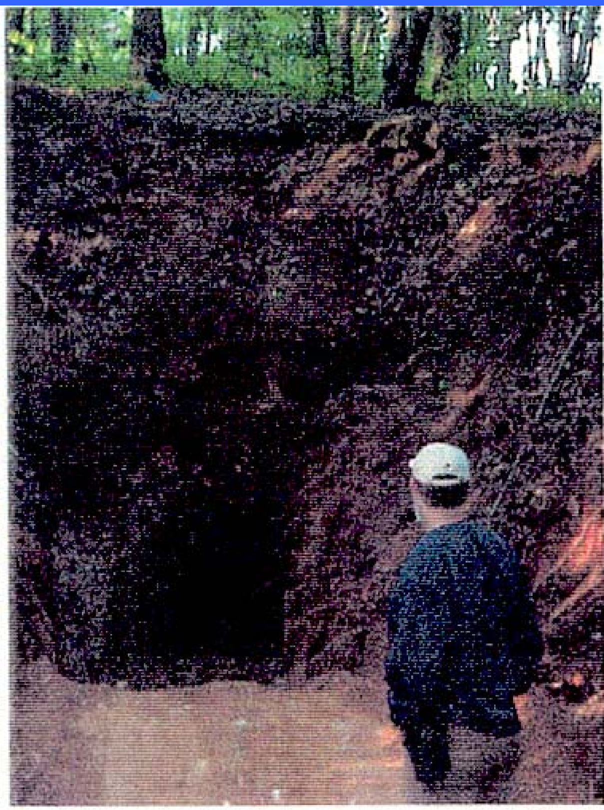
Map of some of the mine workings at Site 1 with the approximate location of the project shown

The following Geophysical testing was performed in the Test Area centered around a NCDOT boring

- Ground Penetrating Radar, DC resistivity, and seismic refraction all along a common 81 m line.
- Gravity, Electromagnetic, and Total Field Magnetic within a 30 m by 30 m grid

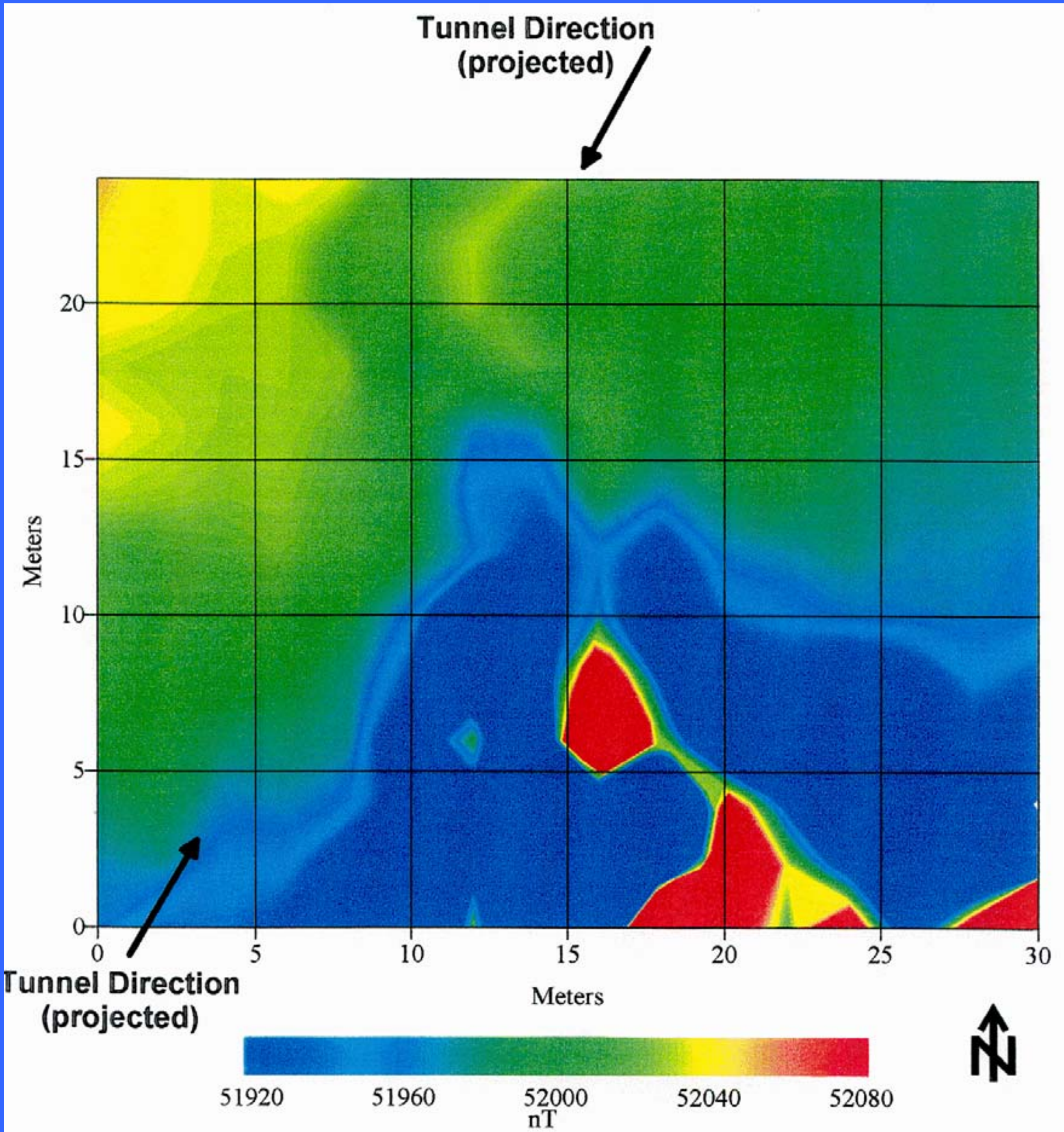
The Test Survey area



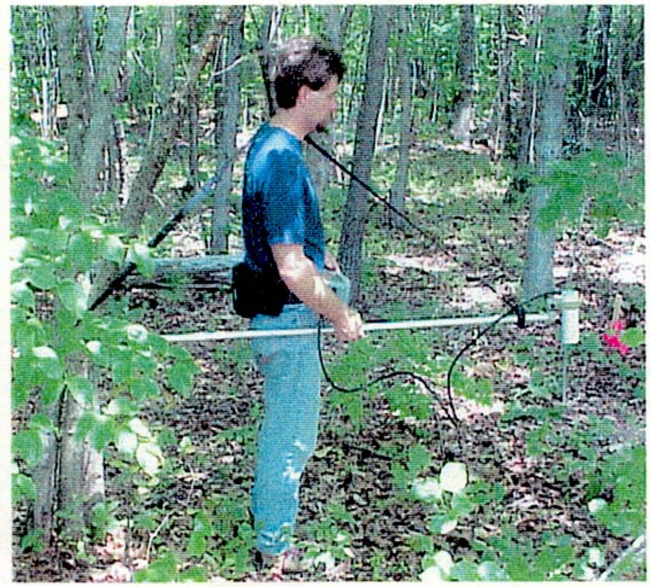


Photograph of the exposed mine tunnel below the geophysical test

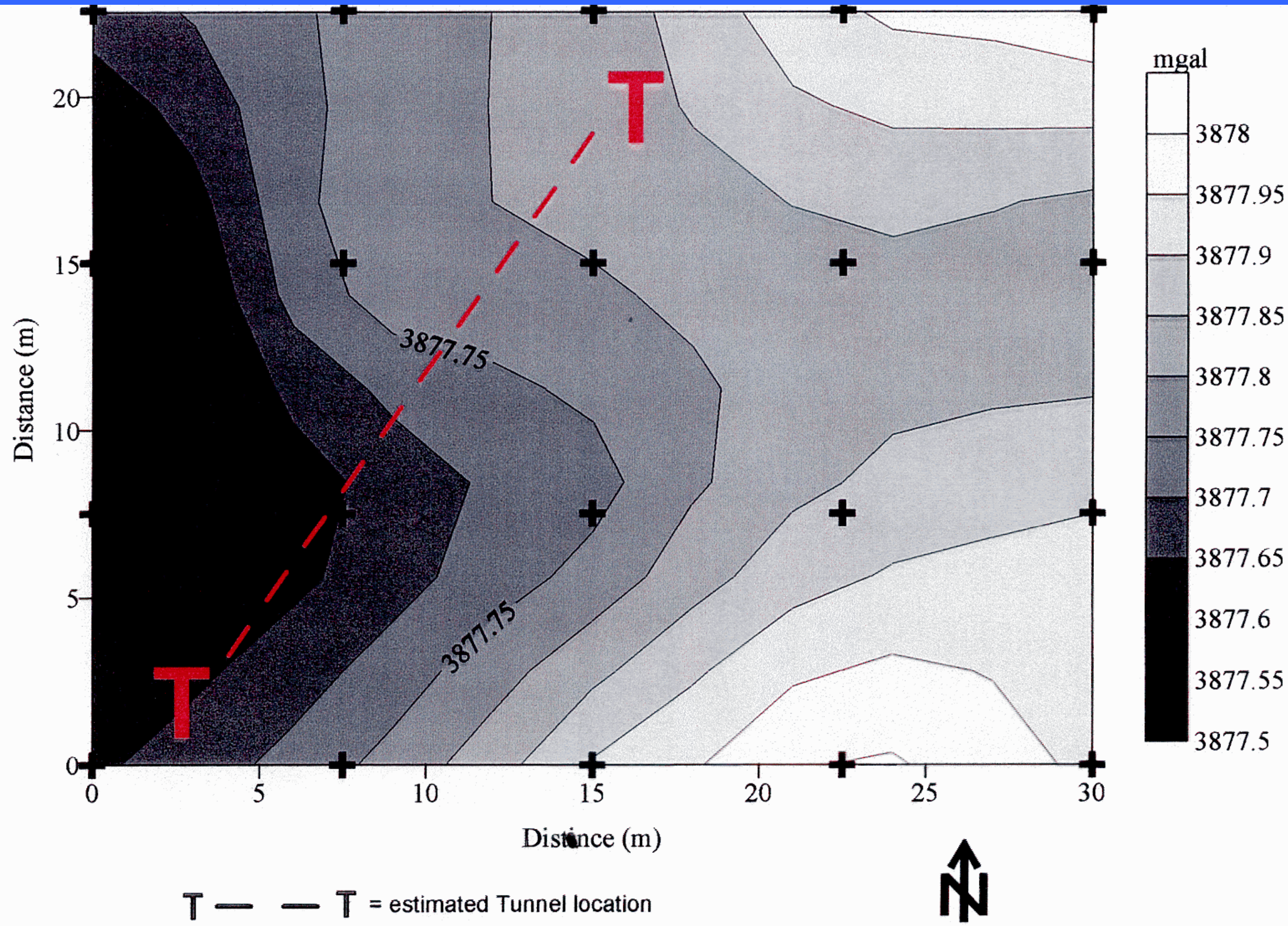
A view across a portion of the main geophysical survey area



Geophex | Color contour plot of total field magnetic data over Test area.

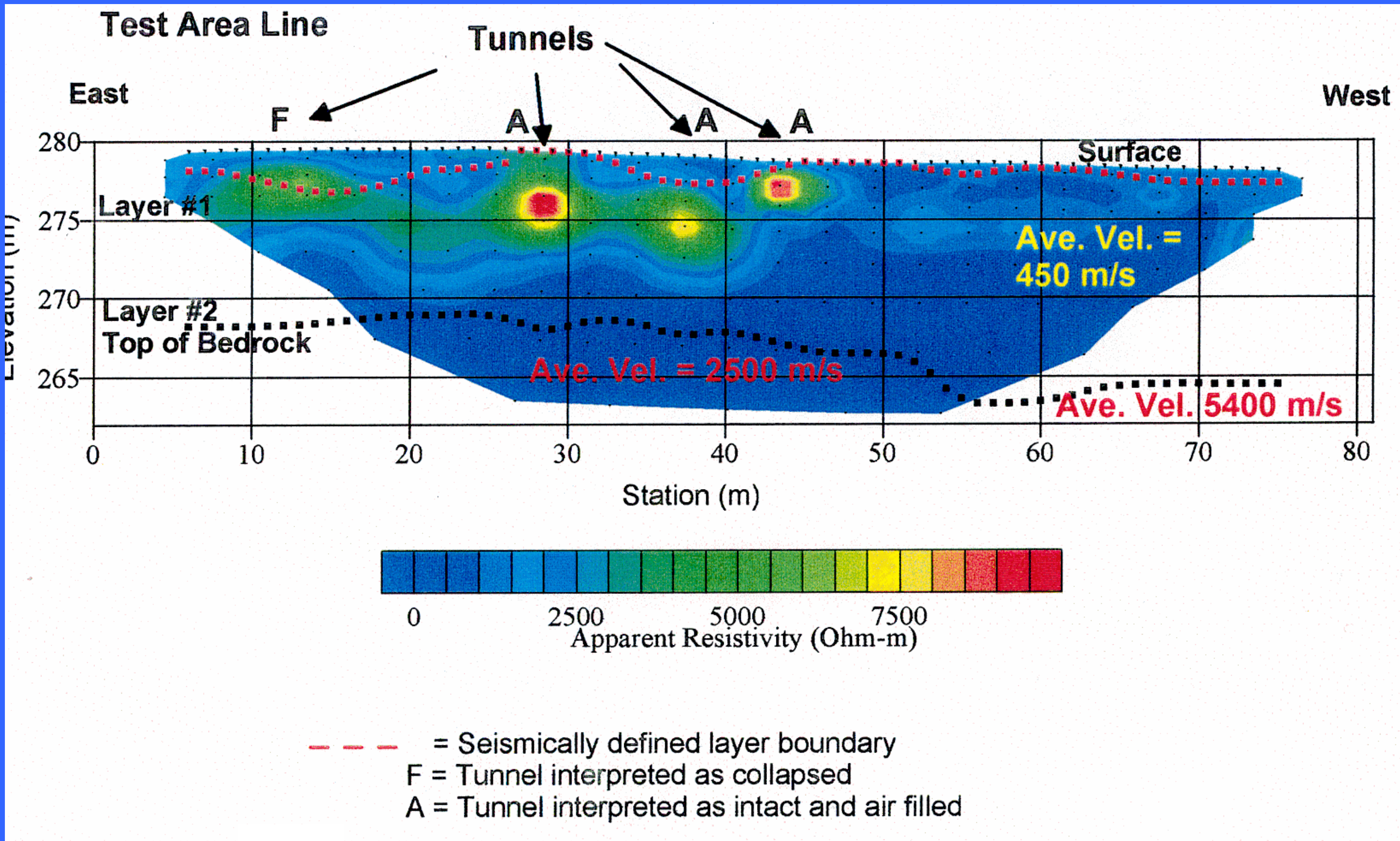


G-858 Total Field Magnetometer



hex . Gravity Data for the Test area.

Results of DC resistivity and seismic refraction in Test area



Geophex

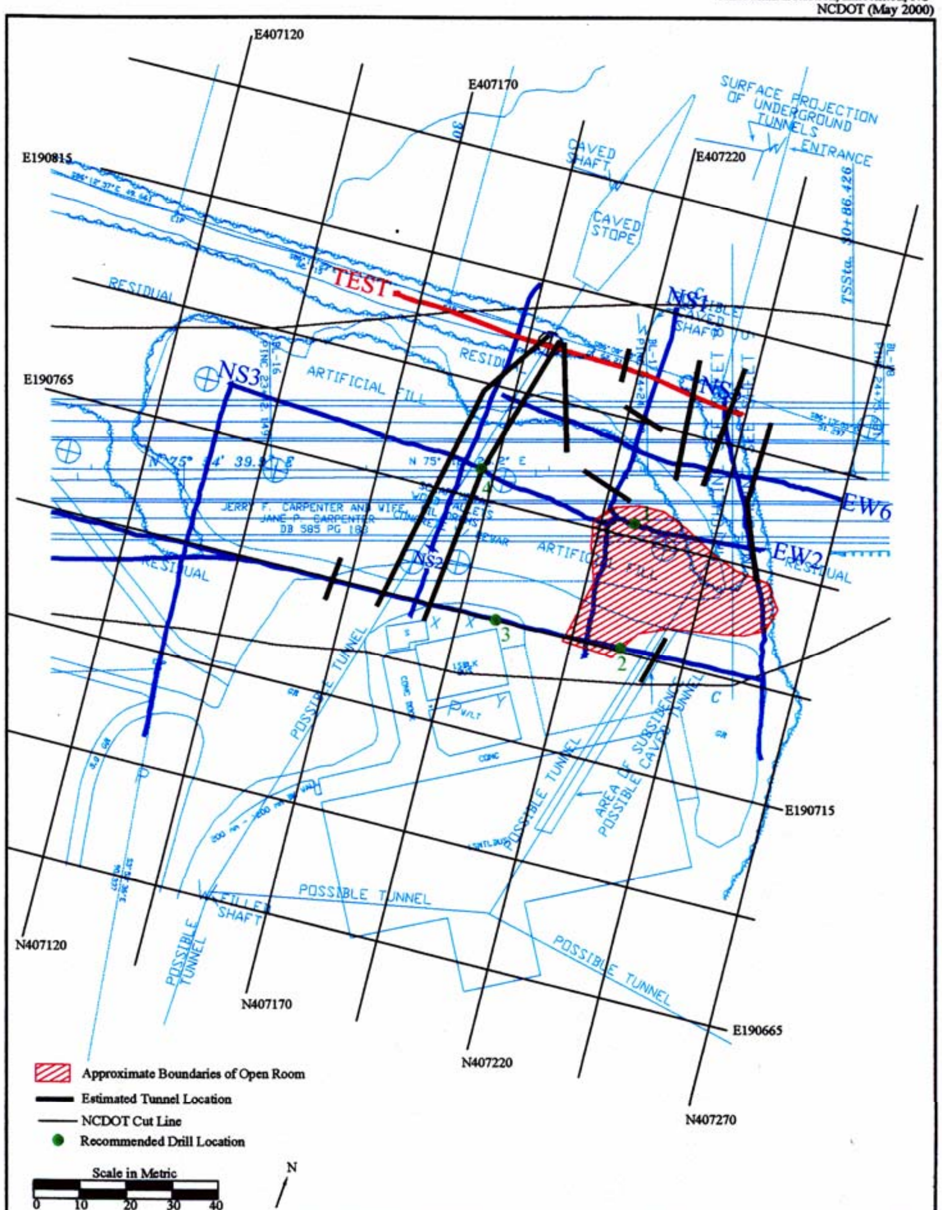
Seismic layers overlying the resistivity data for the Test area.
Note: Layer #2 velocities increase at 50m from 2500 m/s to 5400 m/s

Initial results from Test area

- DC resistivity data interpreted to show 3 potential air filled tunnels and 1 collapsed tunnel
- Seismic refraction data dips slightly under potential tunnel locations
- None of the other methods detected potential tunnels
- DC resistivity and seismic refraction methods chosen to test remainder of site

Geophysical Investigation for Remainder of Site 1

- Investigation centered around area of site most likely to contain tunnels based on historical data
- Eleven DC resistivity profiles run ranging from 81 m to 291 m in length
- Five 72 m long seismic refraction lines run

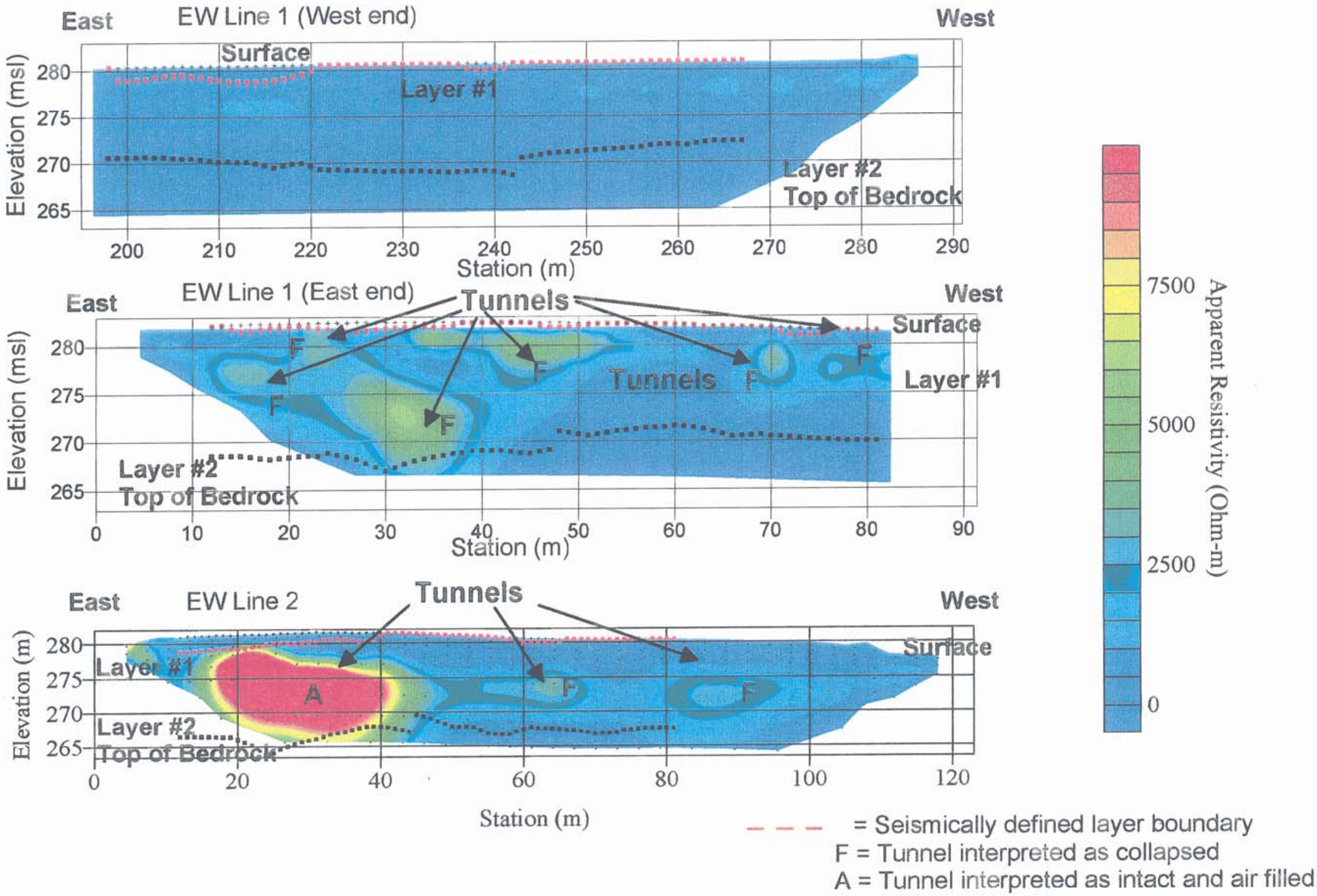


Approximate Boundaries of Open Room
Estimated Tunnel Location
NCDOT Cut Line
Recommended Drill Location

Scale in Metric
0 10 20 30 40

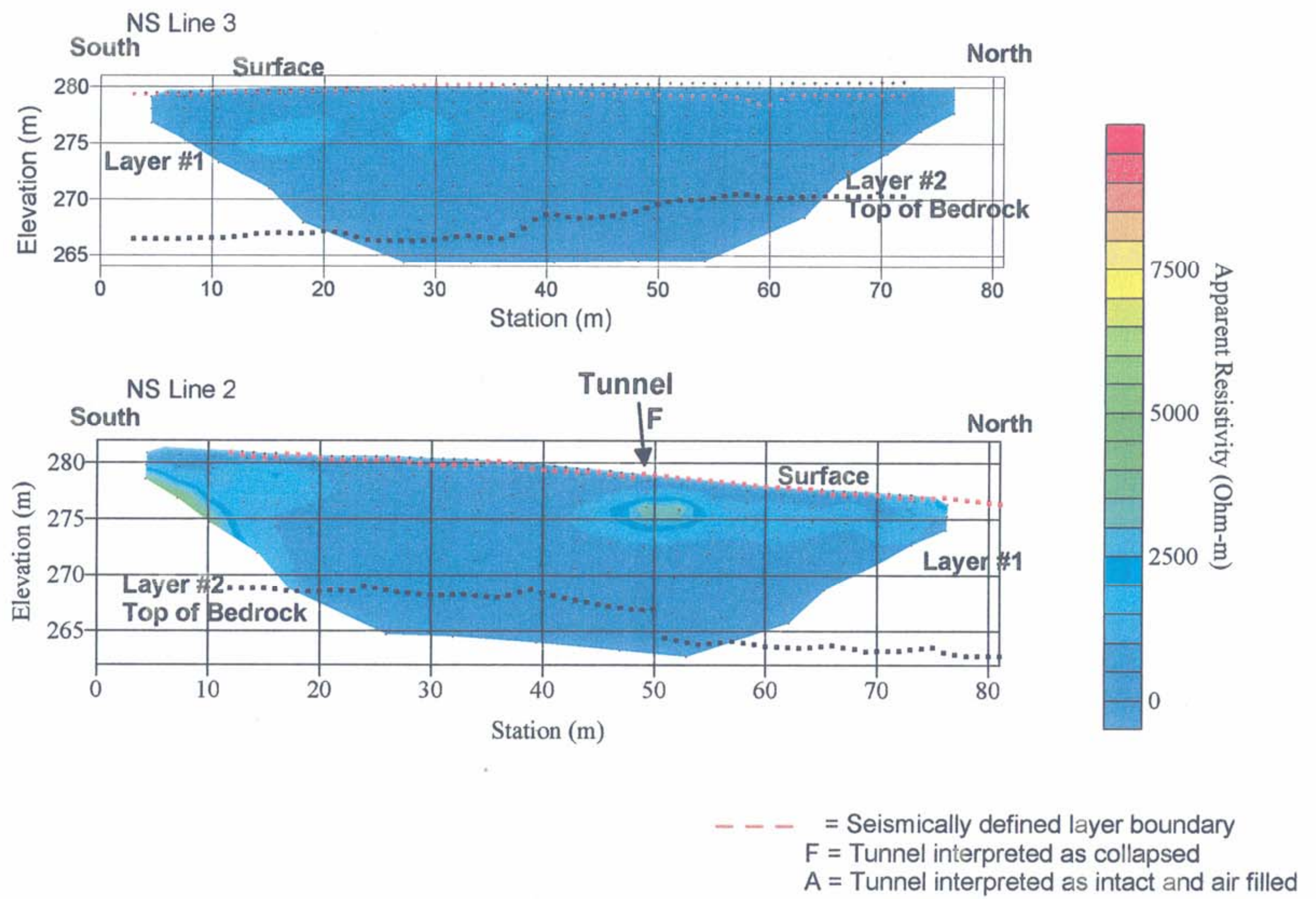
Geophex

Recommended Drill Locations



Geophex

Figure 20. East - West Lincolnton seismic results overlying the coincident resistivity profiles.

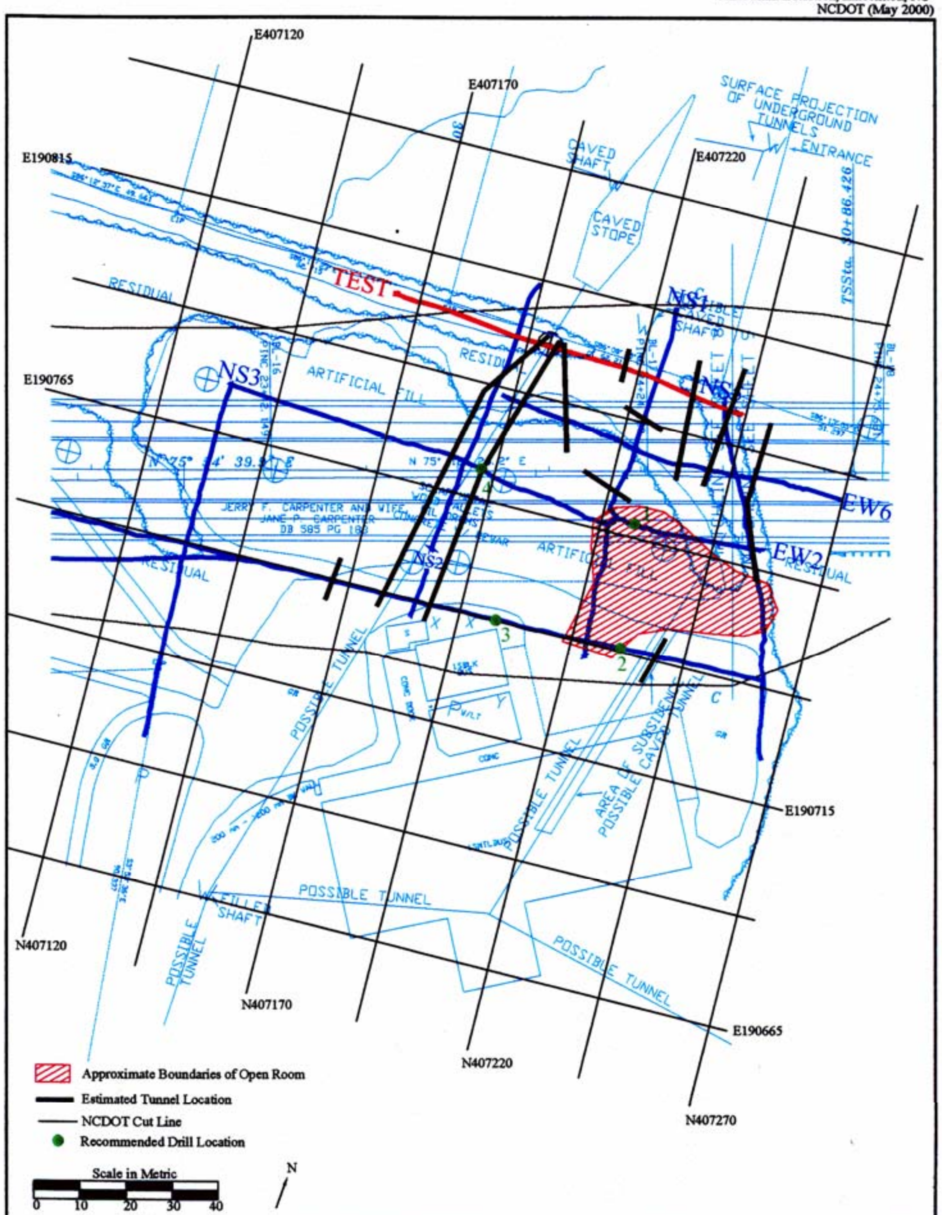


Geophex

Figure 20 cont. North - South Lincolnton seismic results overlying the coincident resistivity profiles.

Results from Site 1 Geophysical Investigation

- Features interpreted as tunnels are in eastern half of study area
- Large feature interpreted as a potential air-filled room in southeastern corner of area tested
- Several filled tunnels suspected
- Proposed 4 borings be performed: #1 to confirm air-filled room/tunnel, #2 and #3 to confirm bedrock, #4 to confirm caved/filled tunnel

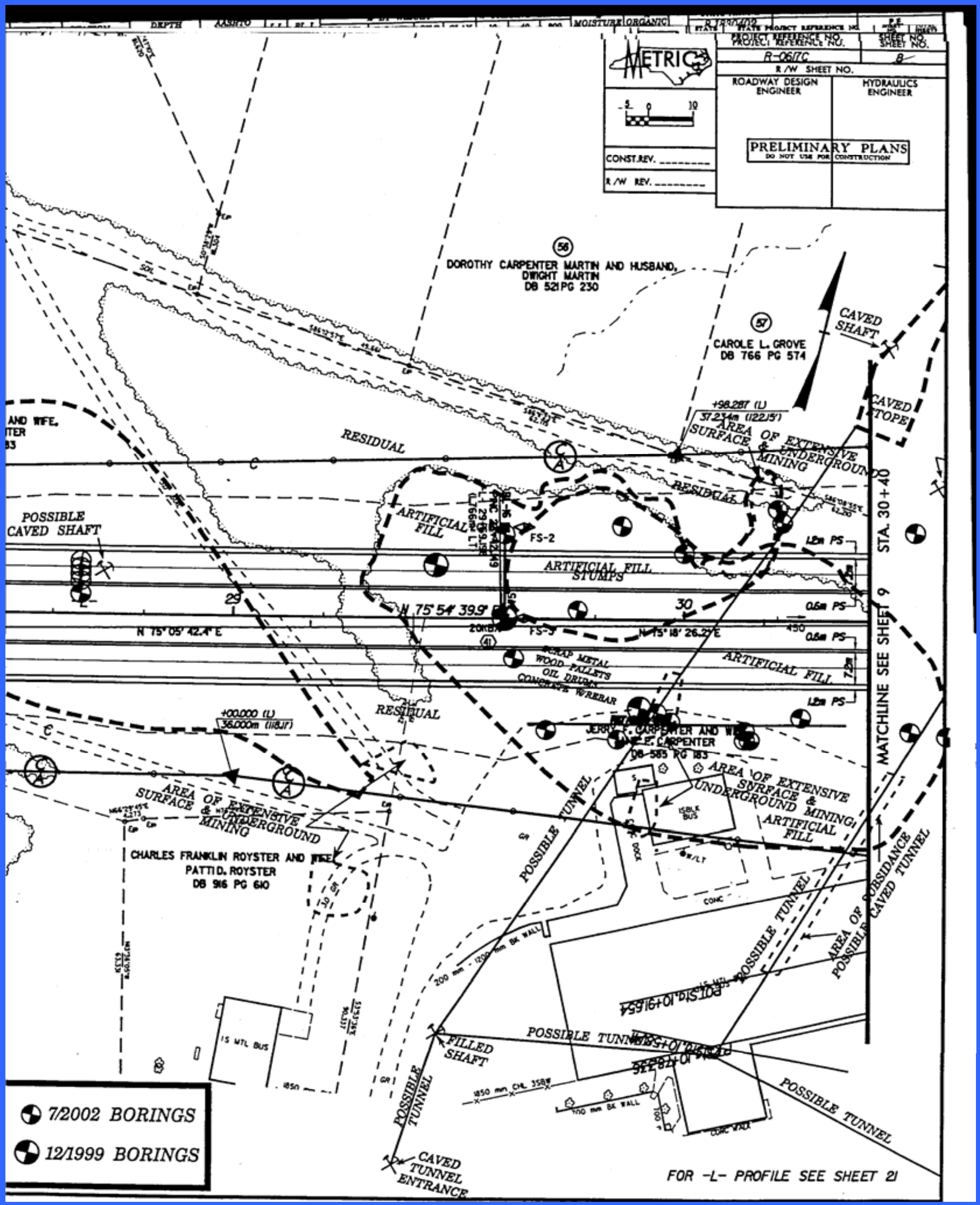


Geophex

Recommended Drill Locations

2000 and 2002 Boring Investigations

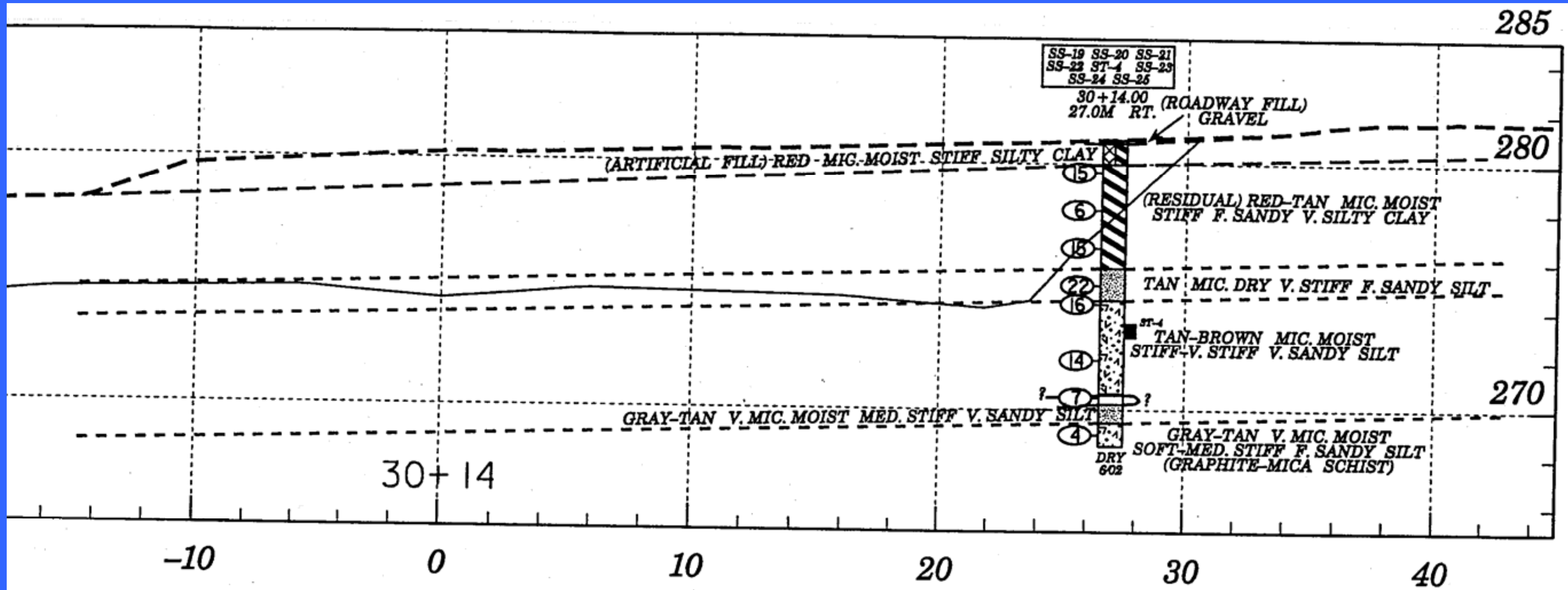
- 11 borings drilled in 2000 to confirm the Geophysical interpretations and in areas adjacent to the Geophysical investigation
- 20 borings drilled in 2002 in areas adjacent to Geophysical investigation
- Down hole camera utilized to confirm presence of air filled voids when encountered

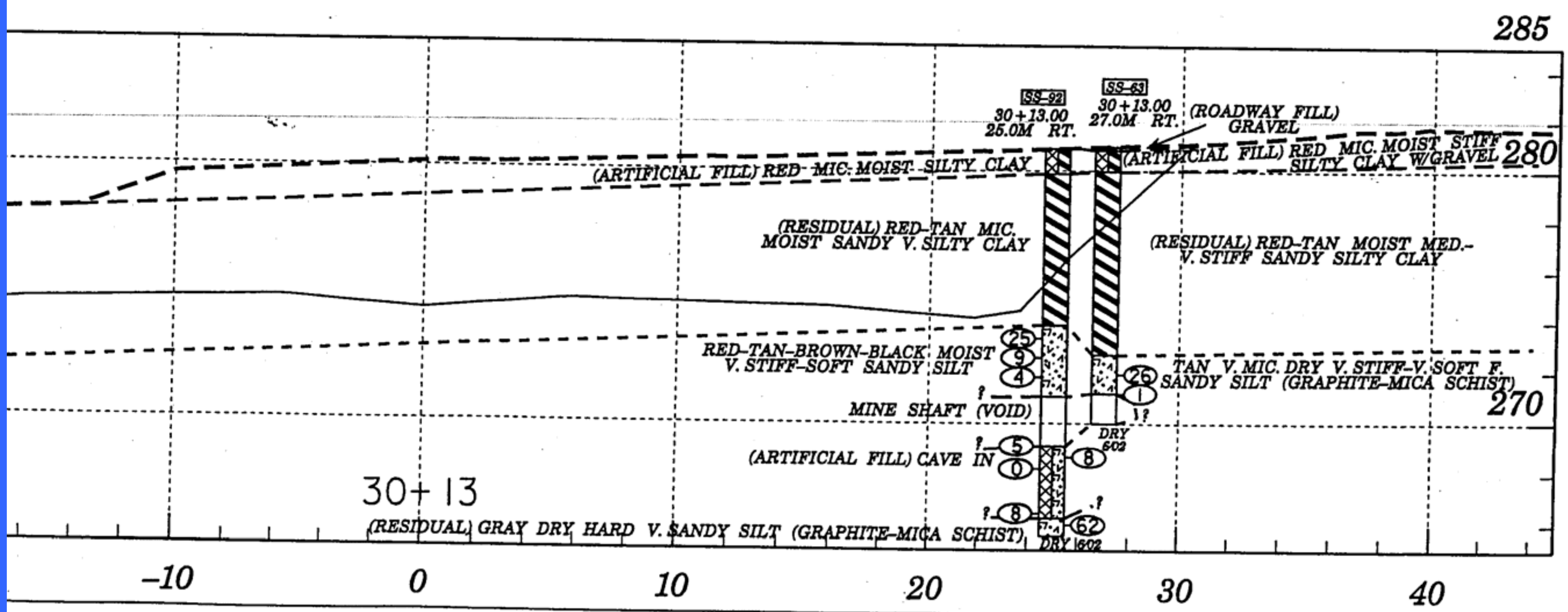


Plan view showing some of the borings performed to confirm the Tunnel locations

Results of Boring Investigations

- The large area interpreted as the “open room/tunnel” had a total of 6 borings placed within its’ limits
- Only 2 of these borings encountered possible tunnels which were collapsed at both locations
- Two other suspected air-filled tunnels were found to be either collapsed or non-existent
- An air-filled room/tunnel was encountered 12 m from the area interpreted as an “open room/tunnel”, and 5 m to 8 m from line EW 1


285
SS-19 SS-20 SS-21
SS-22 ST-4 SS-23
SS-24 SS-25
30+14.00
27.0M RT.
(ROADWAY FILL)
GRAVEL
280
(ARTIFICIAL FILL) RED MIC. MOIST STIFF SILTY CLAY
(RESIDUAL) RED-TAN MIC. MOIST
STIFF F. SANDY V. SILTY CLAY
TAN MIC. DRY V. STIFF F. SANDY SILT
TAN-BROWN MIC. MOIST
STIFF-V. STIFF V. SANDY SILT
270
GRAY-TAN V. MIC. MOIST MED. STIFF V. SANDY SILT
GRAY-TAN V. MIC. MOIST
SOFT-MED. STIFF F. SANDY SILT
(GRAPHITE-MICA SCHIST)
DRY
602
30+14
–10
0
10
20
30
40

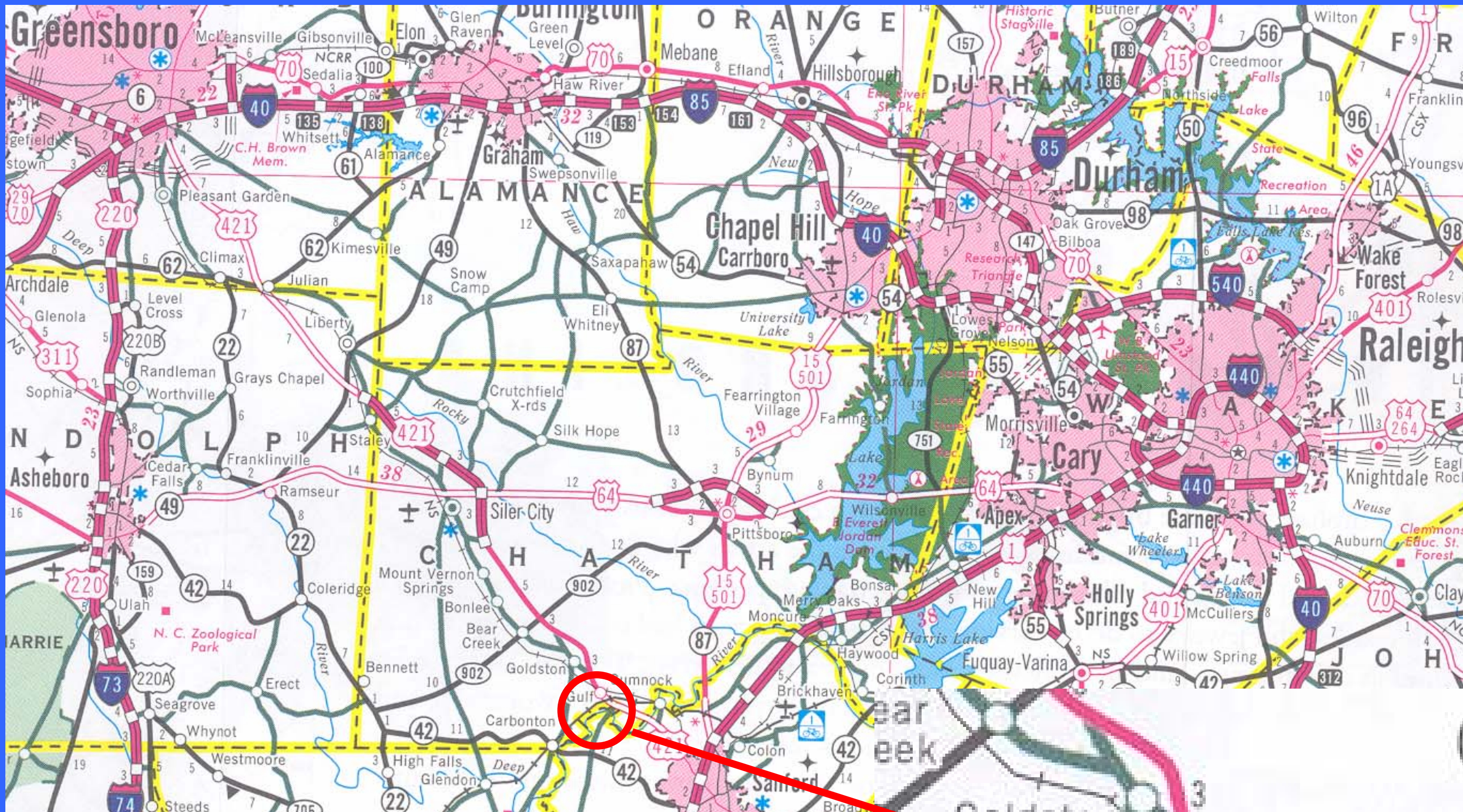

285
SS-62
30+13.00
25.0M RT.
SS-63
30+13.00
27.0M RT.
(ROADWAY FILL)
GRAVEL
280
(ARTIFICIAL FILL) RED MIC. MOIST SILTY CLAY
(ARTIFICIAL FILL) RED MIC. MOIST STIFF
SILTY CLAY W/GRAVEL
(RESIDUAL) RED-TAN MIC.
MOIST SANDY V. SILTY CLAY
(RESIDUAL) RED-TAN MOIST MED.-
V. STIFF SANDY SILTY CLAY
RED-TAN-BROWN-BLACK MOIST
V. STIFF-SOFT SANDY SILT
TAN V. MIC. DRY V. STIFF-V. SOFT F.
SANDY SILT (GRAPHITE-MICA SCHIST)
270
MINE SHAFT (VOID)
DRY
602
(ARTIFICIAL FILL) CAVE IN
30+13
(RESIDUAL) GRAY DRY HARD V. SANDY SILT (GRAPHITE-MICA SCHIST)
DRY
602
–10
0
10
20
30
40

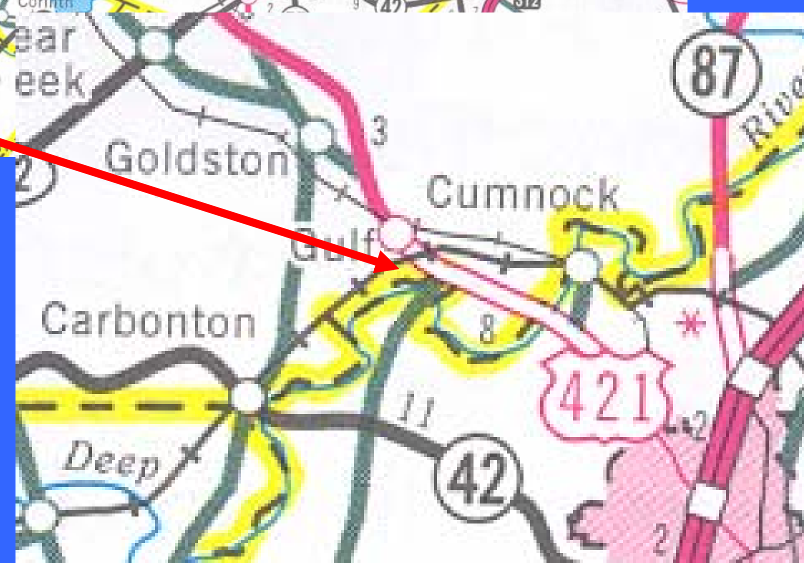
Site 1 Conclusions/Recommendations

- Overall geophysics only located caved/filled tunnels at a few locations and did not locate any open tunnel locations
- After the the project is let and the gross excavation is completed, more borings and geophysics will be performed
- Any tunnels or rooms that are discovered or exposed will be excavated and back-filled with rip-rap and/or grout

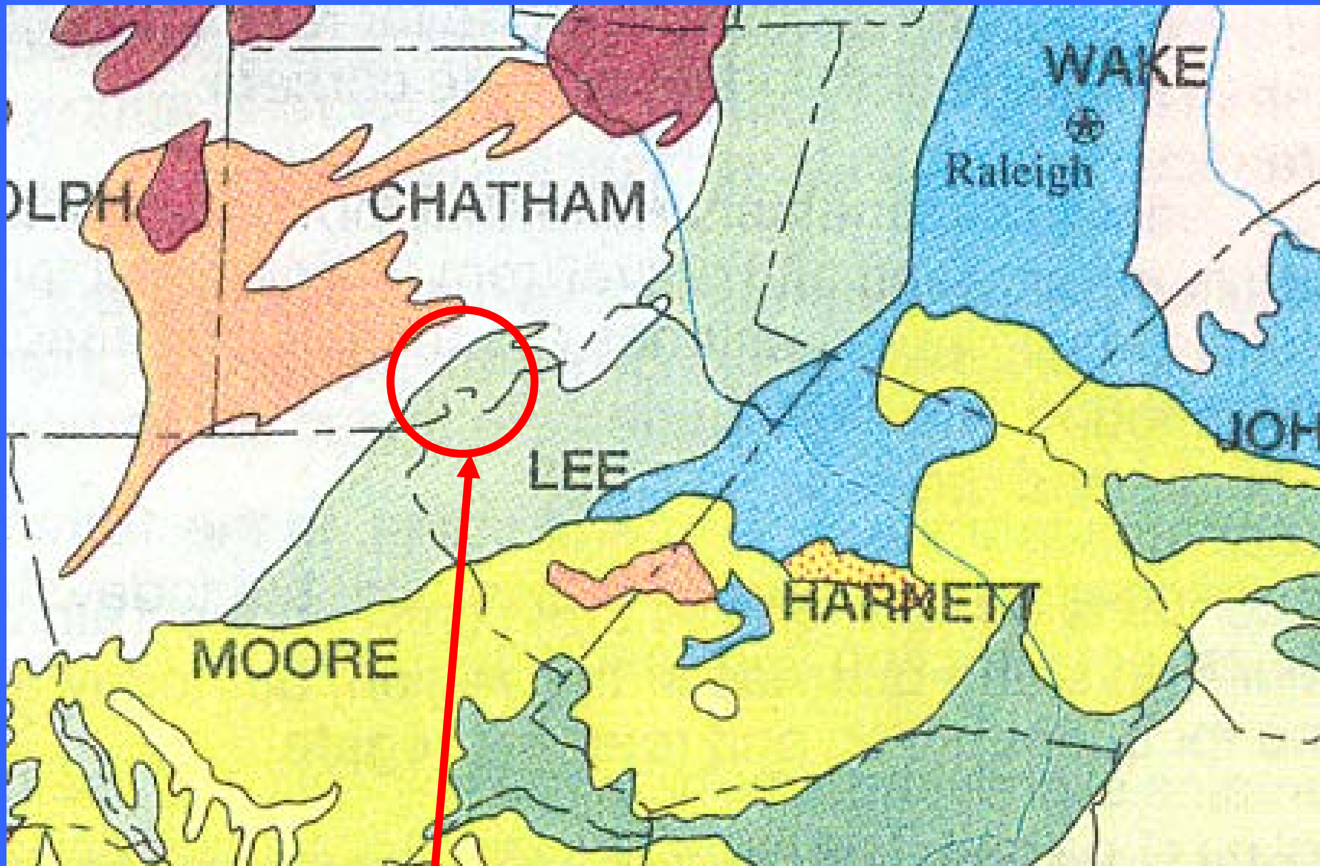
R-2610A, Chatham Co., NC

Site 2, Coal Mine


Greensboro
Burlington
ORANGE
DURHAM
Durham
Chapel Hill
Carrboro
Hillsborough
Mebane
Graham
ALAMANCE
Raleigh
Cary
Apex
Garner
Wake Forest
Morrisville
Holly Springs
Fuquay-Varina
Asheboro
Siler City
Pittsboro
CHATHAM
Goldston
Cumnock
Gulf
Carbonton
Sanford
Bennett
Bear Creek
Bonlee
Moncure
Ramseur
Randleman
Liberty
Snow Camp
Saxapahaw
Silk Hope
Crutchfield X-rds
Staley
Julian
Climax
Franklinville
Coleridge
Seagrove
Whynot
Westmoore
High Falls
Glendon
Knightdale
Jordan Lake


Goldston
Cumnock
Gulf
Carbonton
Deep
87
42
421

Site 2

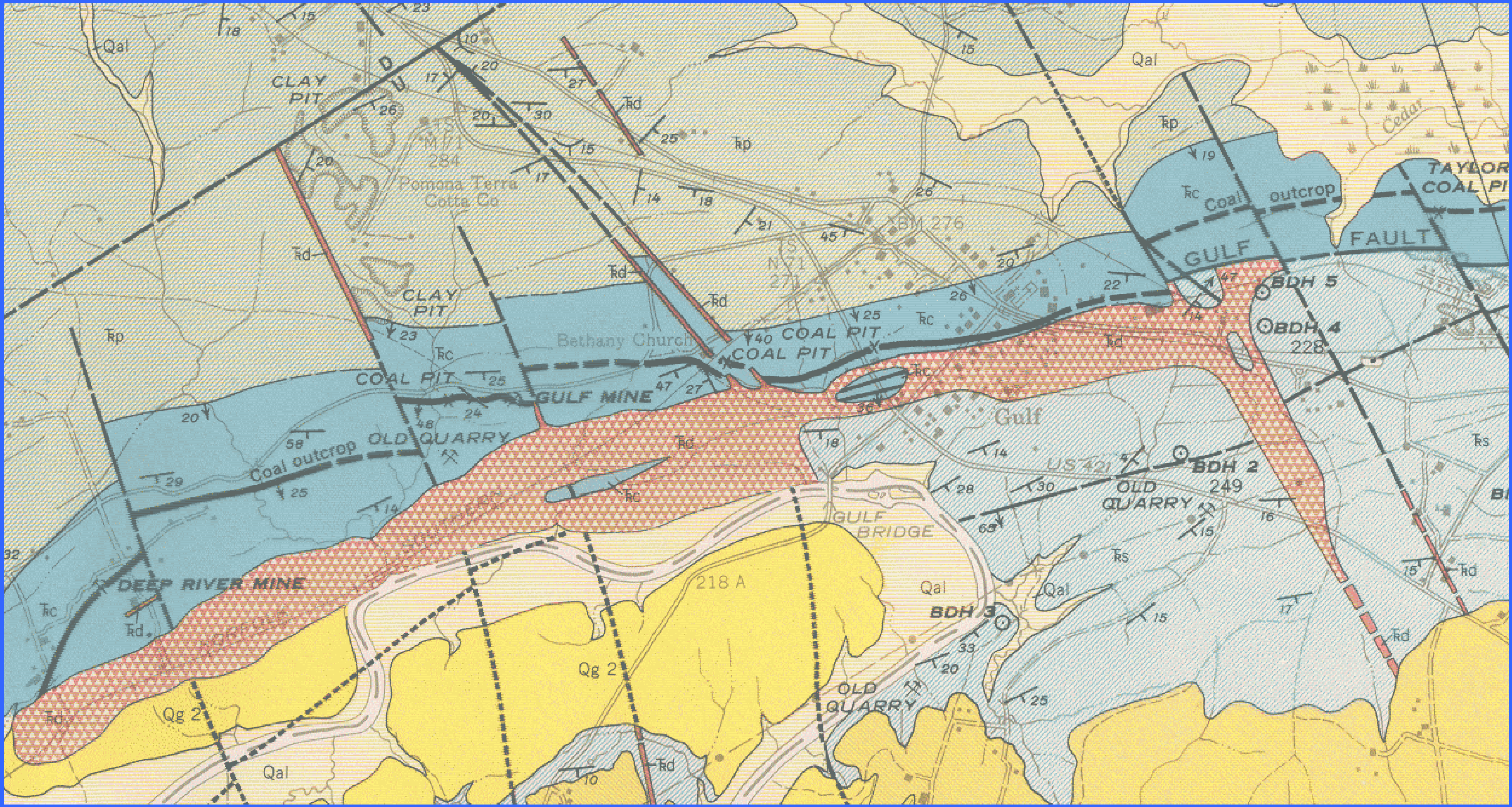


Site 2

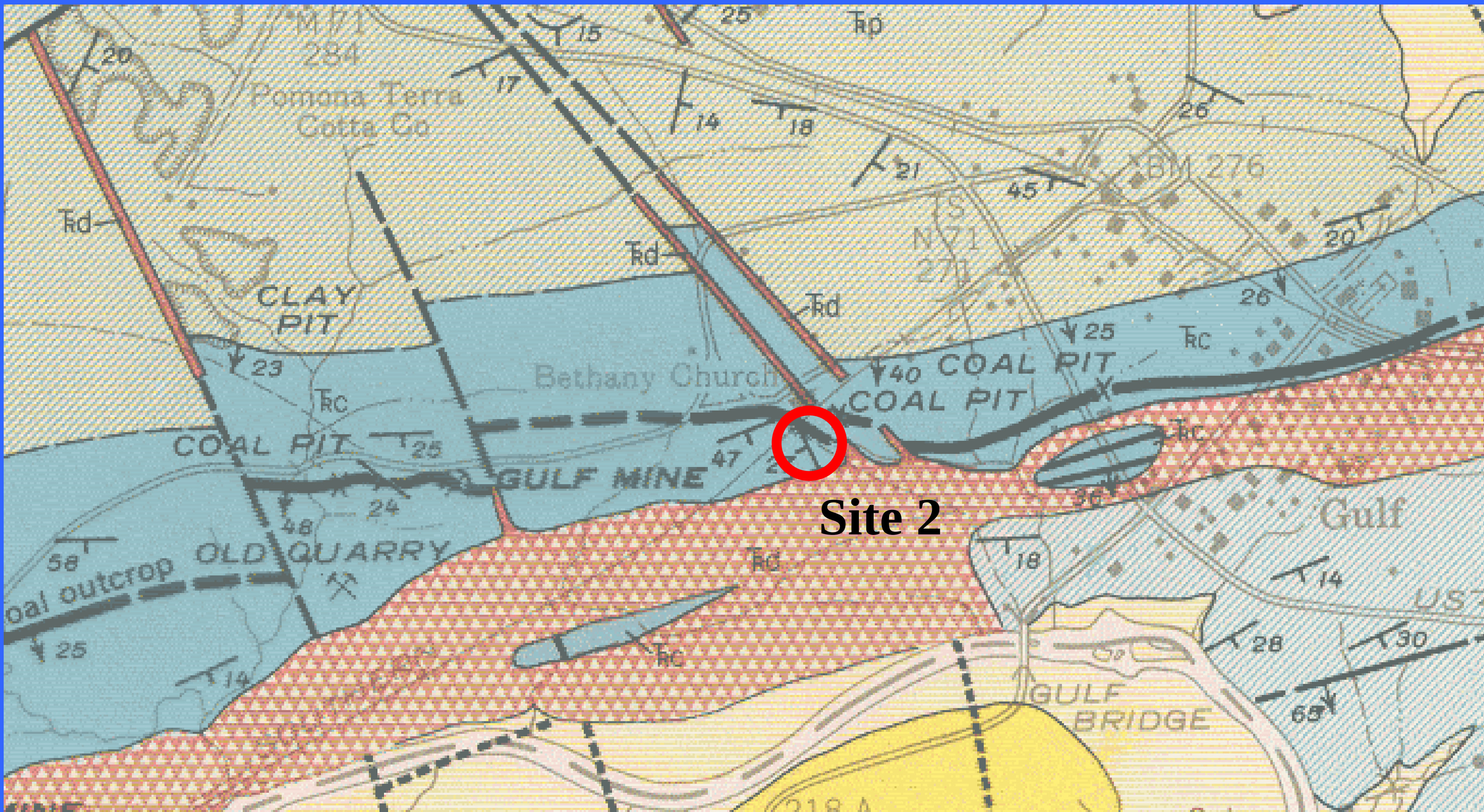
Triassic

Dan River Group, undivided -
Stoneville Formation - conglomerate, sandstone and mudstone.
Cow Branch Formation - mudstone.
Pine Hall Formation - sandstone, mudstone and conglomerate.

Chatham Group, undivided -
Sanford Formation - conglomerate, sandstone and mudstone.
Cumnock Formation.- sandstone and mudstone.
Pekin Formation - conglomerate, sandstone and mudstone.

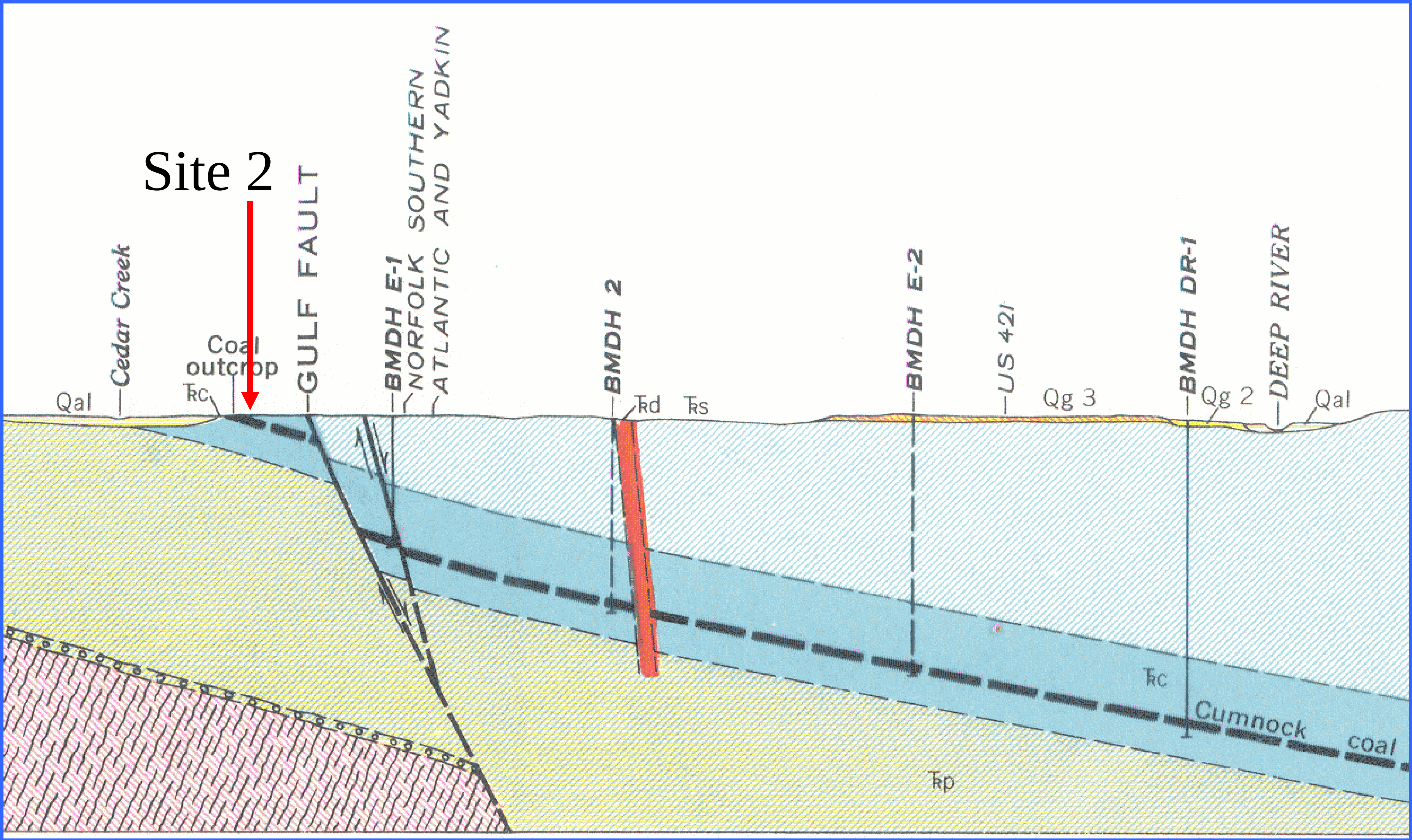


Mining in the Deep River Coal Field occurred from the 1750's with the first known shafts sunk in the 1850's. The last successful commercial coal mining ended in the 1930's.



Coal outcrops at the surface in the area of Site 2 with faulting and diabase occurring throughout the coal beds.

Site 2 Geologic Profile



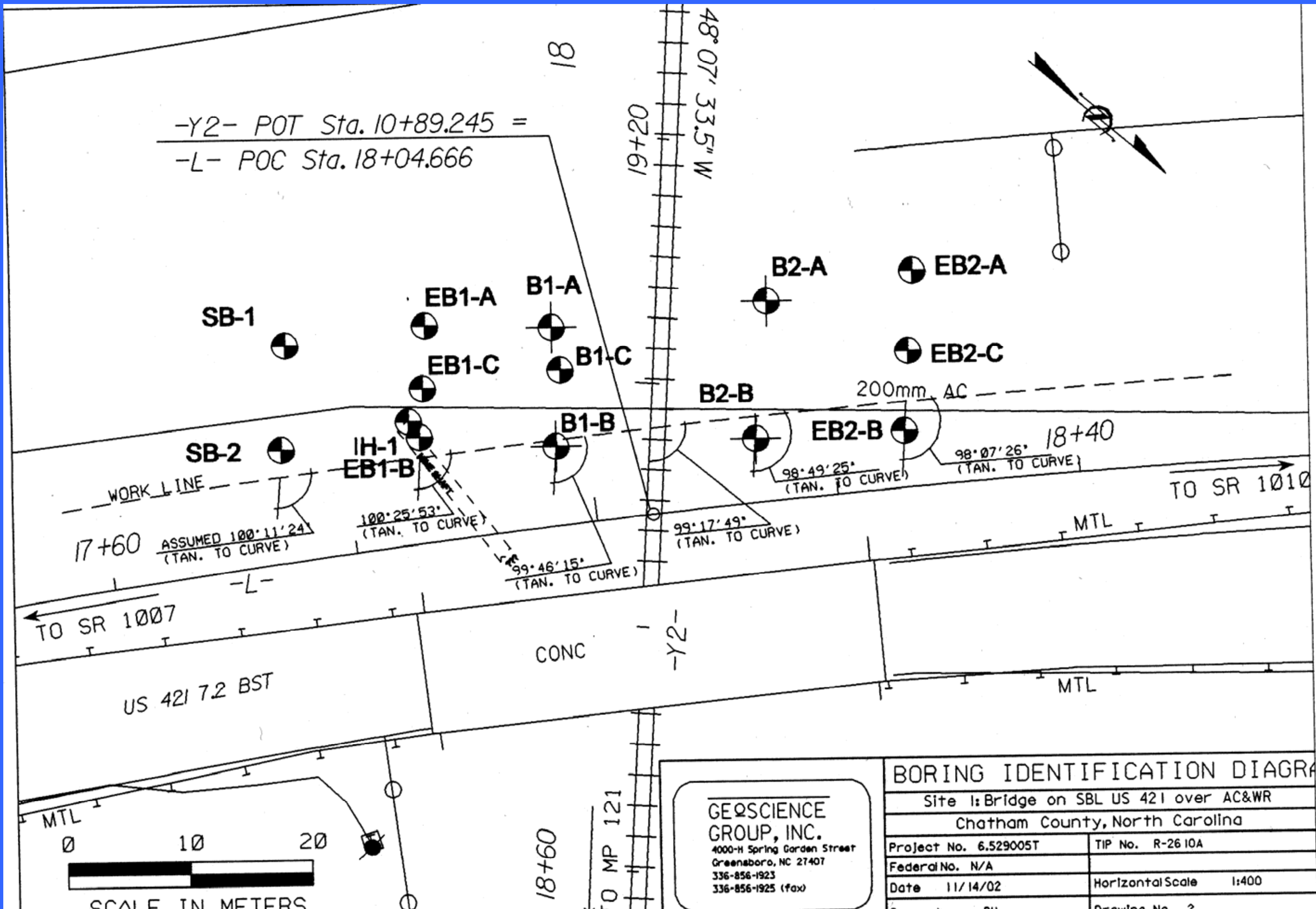
View of the US 421 bridge at Gulf, NC

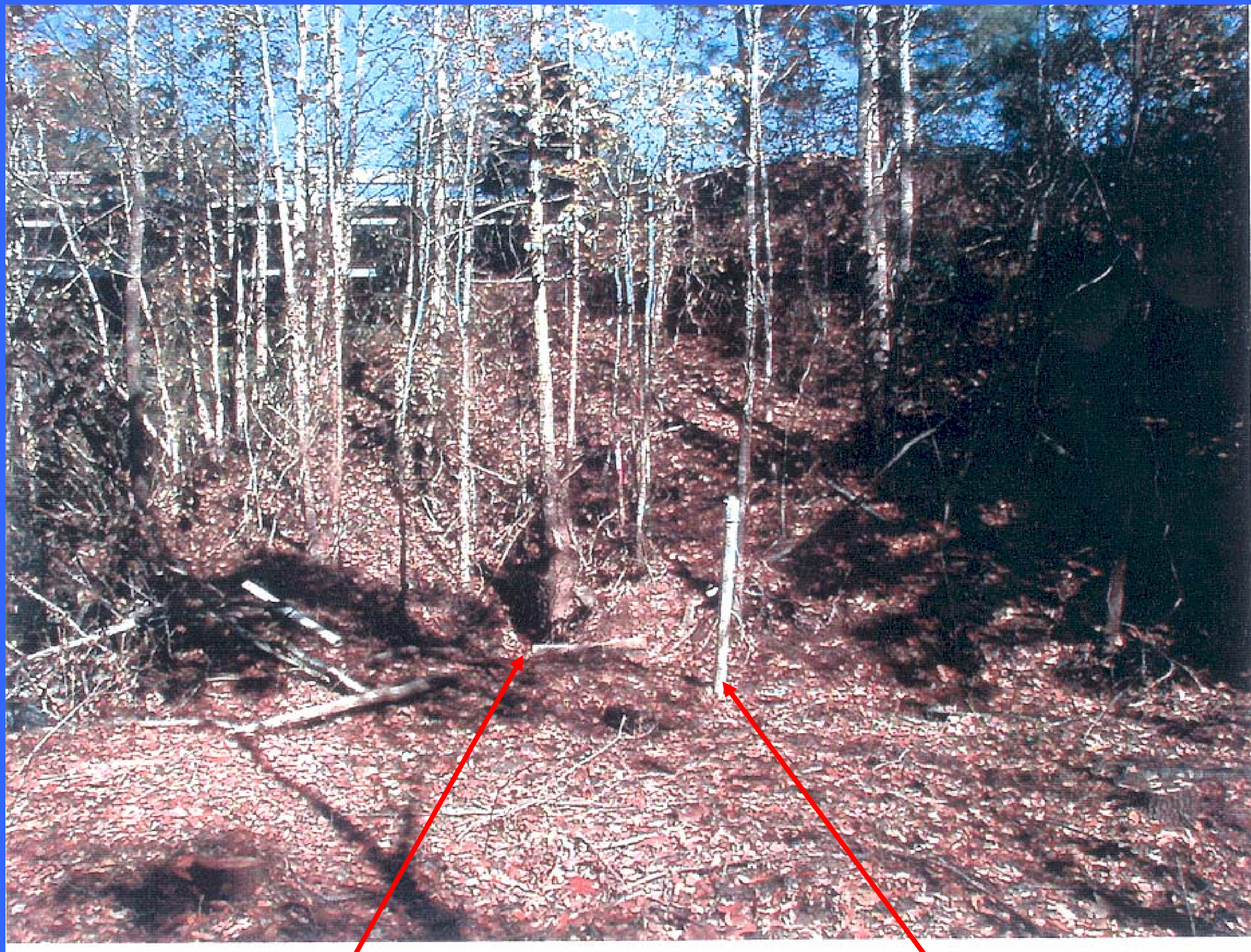
No shafts were encountered during the roadway investigation performed in 2001

When investigating for the bridge crossing the AC&WR Railroad, boring EB1-B encountered a shaft from a depth of 3 meters to approximately 20 meters

Several others borings were drilled trying to locate additional shafts. Only one boring, an inclined hole near EB1-B, encountered a shaft

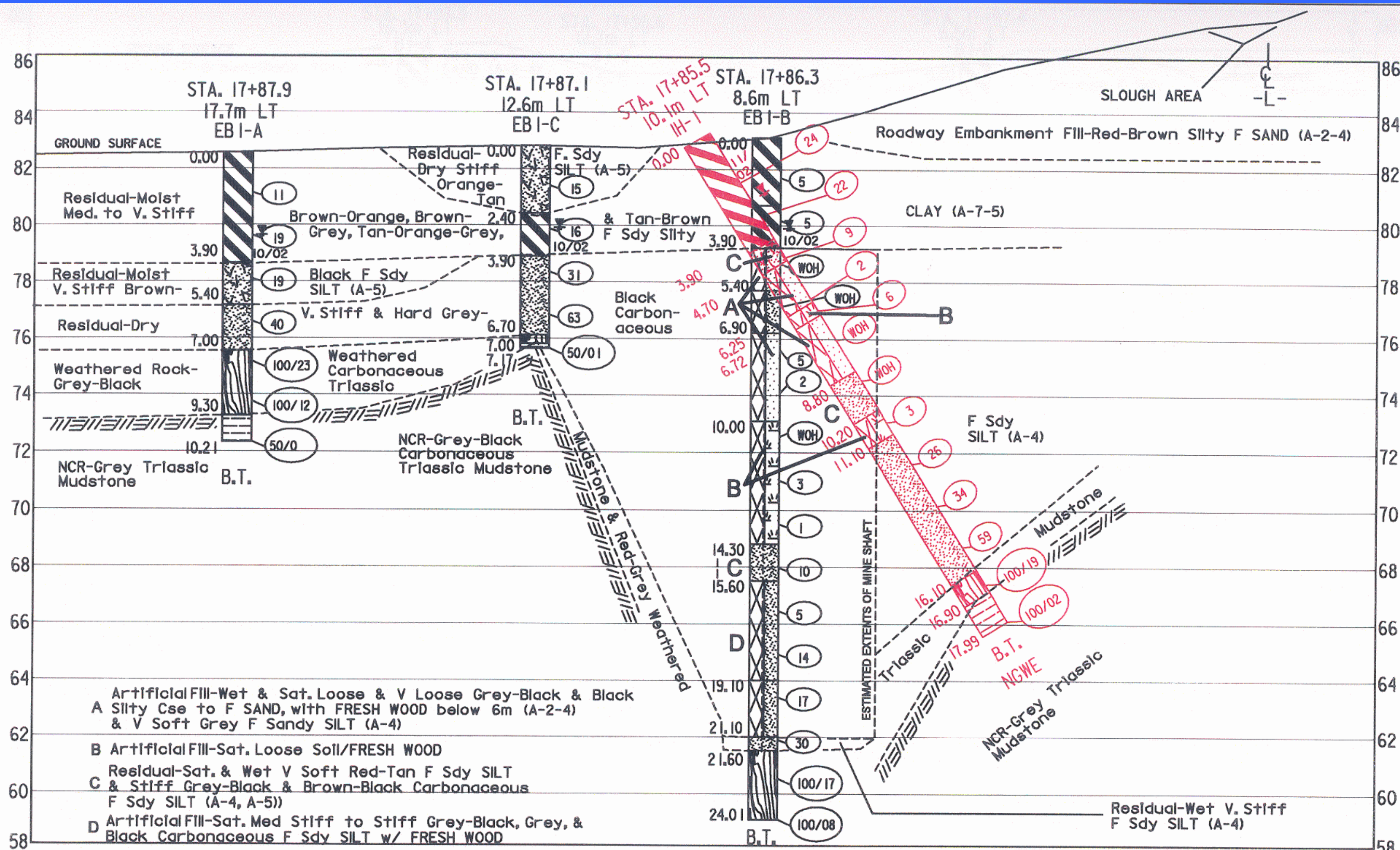
Initial Boring Investigation at Site 2

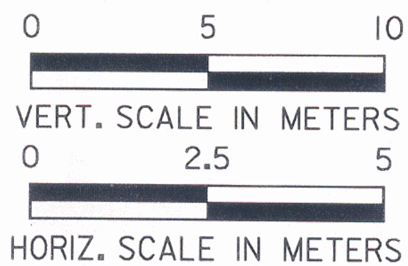




Boring EB1-B and subsidence

Boring IH-1





GEOSCIENCE GROUP, INC.
4000-H Spring Garden Street
Greensboro, NC 27407
336-856-1923
336-856-1925 (fax)

CROSS-SECTION THROUGH END BENT-1

Site 1: Bridge on SBL US 421 over AC&WR

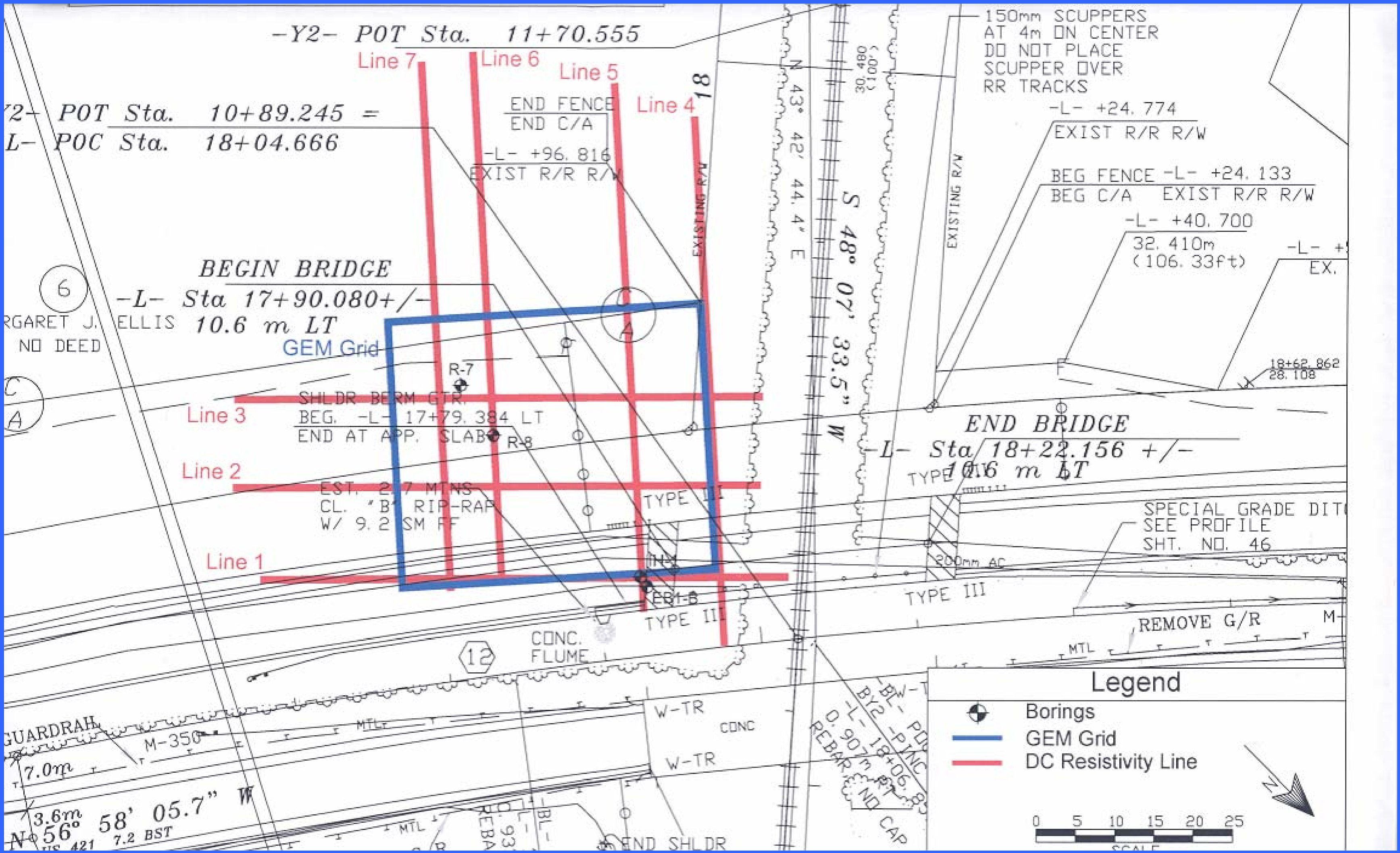
Chatham County, North Carolina

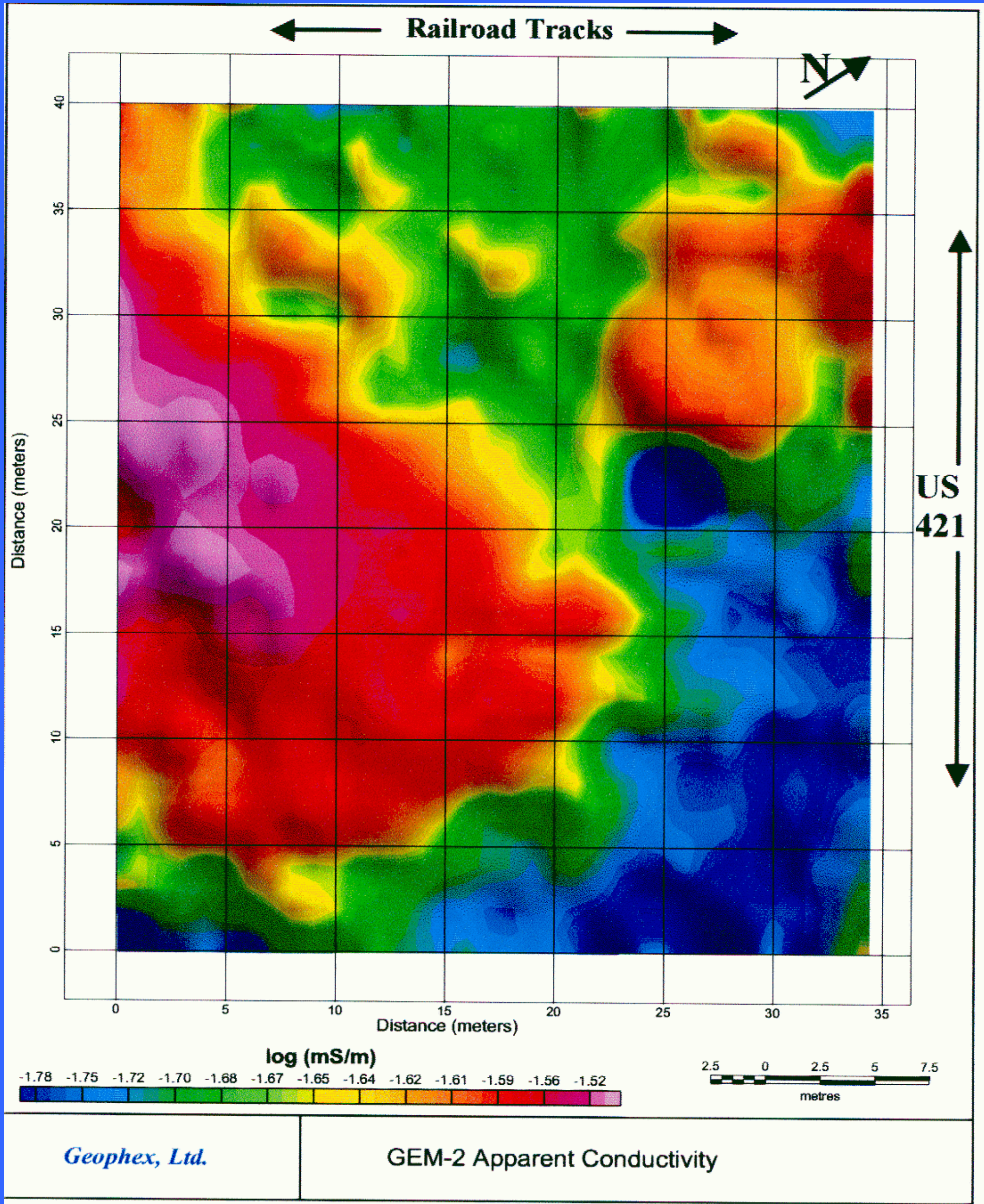
Project No. 6.529005T	TIP No. R-2610A
Federal No. N/A	Vert. Scale 1:200
Date 11/14/02	Horiz. Scale 1:100
Drawn by DH	Drawing No. 5A

Findings from Initial Boring Investigation

- Mine shaft encountered in borings EB1-B and IH-1
- Downhole camera confirmed placed timbers and a partially open side tunnel
- Decided to use geophysics to help determine lateral extent of tunnels

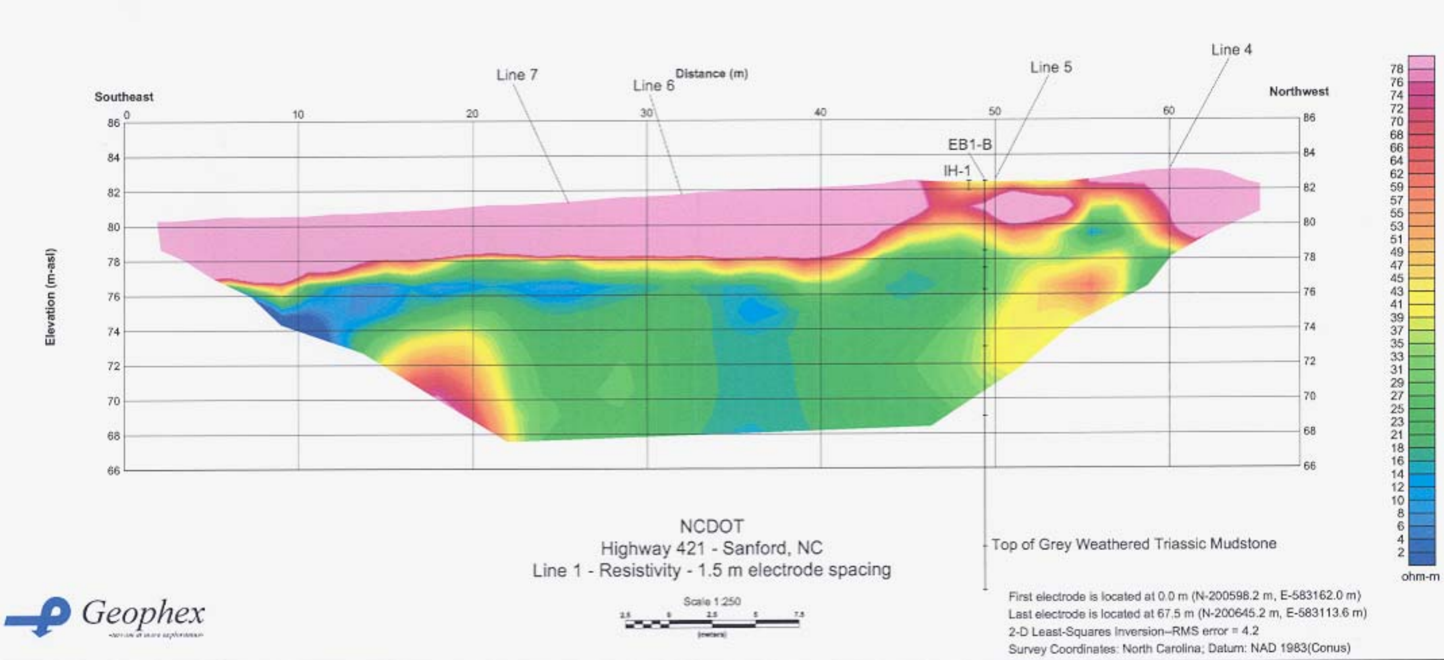
Seven DC resistivity lines 67.5 m long and a 34.5 m by 40 m electromagnetic grid were performed at the site

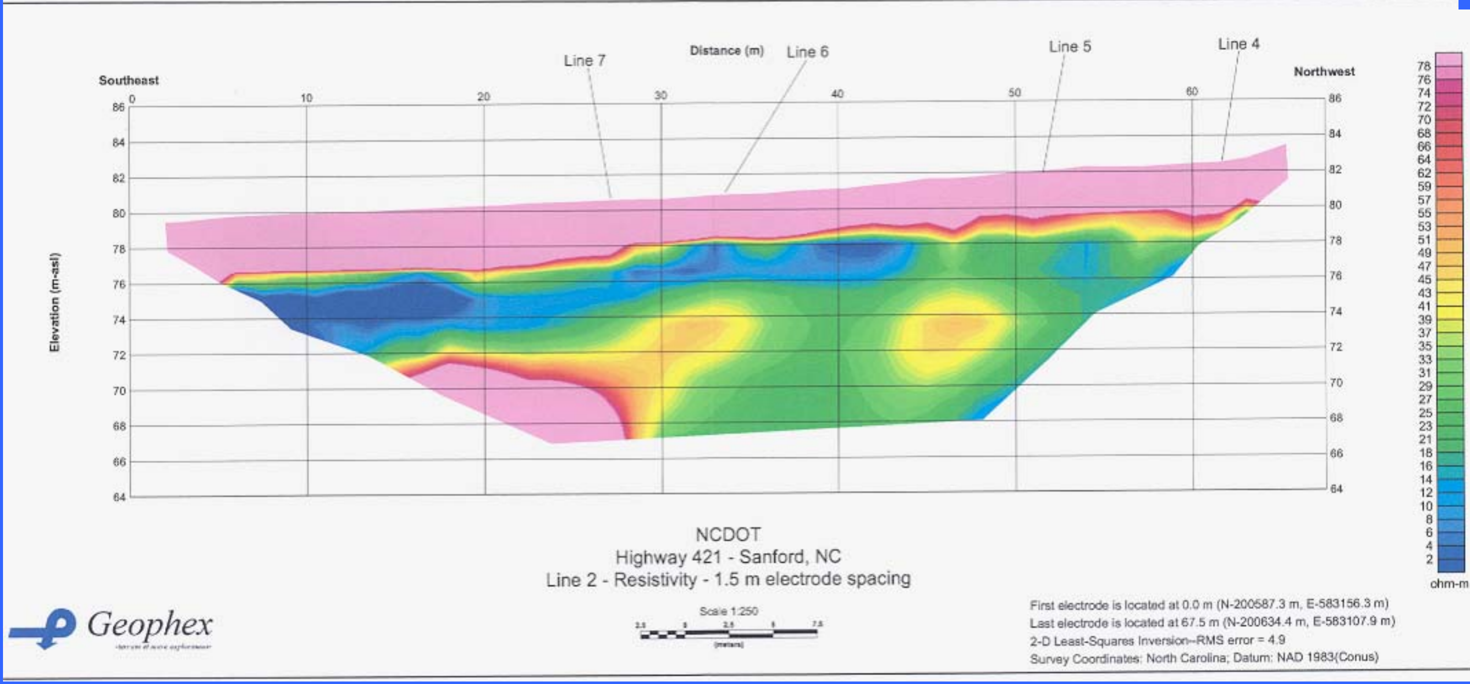


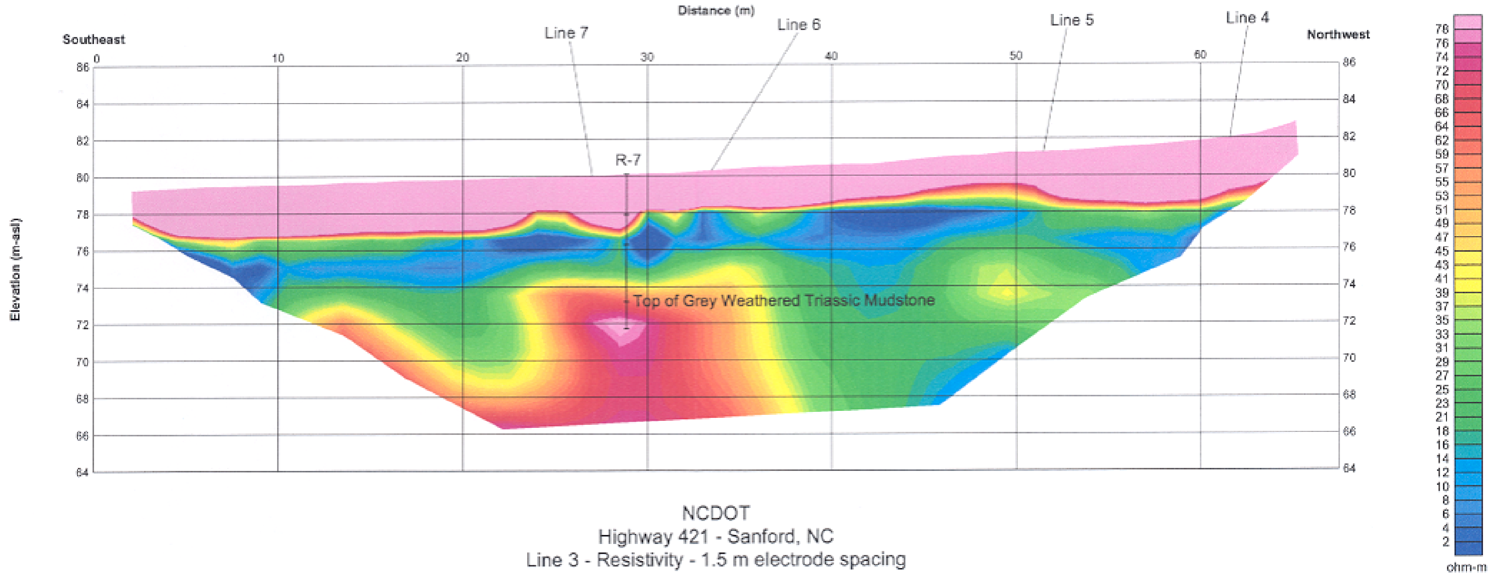


Apparent Conductivity data from the GEM-2 at R-2610, Gulf, NC

GEM-2 data acquisition at R-2610, Gulf, NC


Southeast
Northwest
Distance (m)
Elevation (m-asl)
Line 7
Line 6
Line 5
Line 4
EB1-B
IH-1
Top of Grey Weathered Triassic Mudstone
ohm-m
NCDOT
Highway 421 - Sanford, NC
Line 1 - Resistivity - 1.5 m electrode spacing
Geophex
Scale 1:250
First electrode is located at 0.0 m (N-200598.2 m, E-583162.0 m)
Last electrode is located at 67.5 m (N-200645.2 m, E-583113.6 m)
2-D Least-Squares Inversion--RMS error = 4.2
Survey Coordinates: North Carolina; Datum: NAD 1983(Conus)


Southeast
Northwest
Distance (m)
Elevation (m-asl)
Line 7
Line 6
Line 5
Line 4
ohm-m
NCDOT
Highway 421 - Sanford, NC
Line 2 - Resistivity - 1.5 m electrode spacing
Geophex
Scale 1:250
First electrode is located at 0.0 m (N-200587.3 m, E-583156.3 m)
Last electrode is located at 67.5 m (N-200634.4 m, E-583107.9 m)
2-D Least-Squares Inversion--RMS error = 4.9
Survey Coordinates: North Carolina; Datum: NAD 1983(Conus)

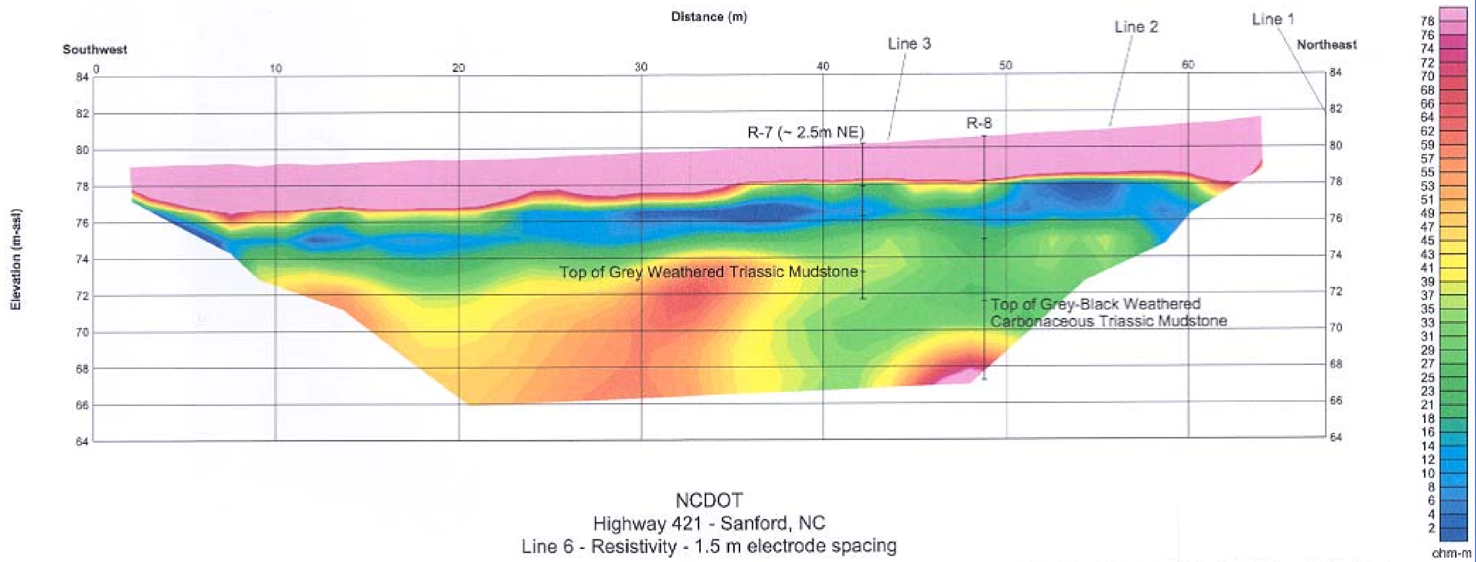


NCDOT
Highway 421 - Sanford, NC
Line 3 - Resistivity - 1.5 m electrode spacing

Geophex

Scale 1:250

First electrode is located at 0.0 m (N-200579.4 m, E-583148.3 m)
Last electrode is located at 67.5 m (N-200626.4 m, E-583099.9 m)
2-D Least-Squares Inversion--RMS error = 4.5
Survey Coordinates: North Carolina; Datum: NAD 1983(Conus)



NCDOT
Highway 421 - Sanford, NC
Line 6 - Resistivity - 1.5 m electrode spacing

Geophex

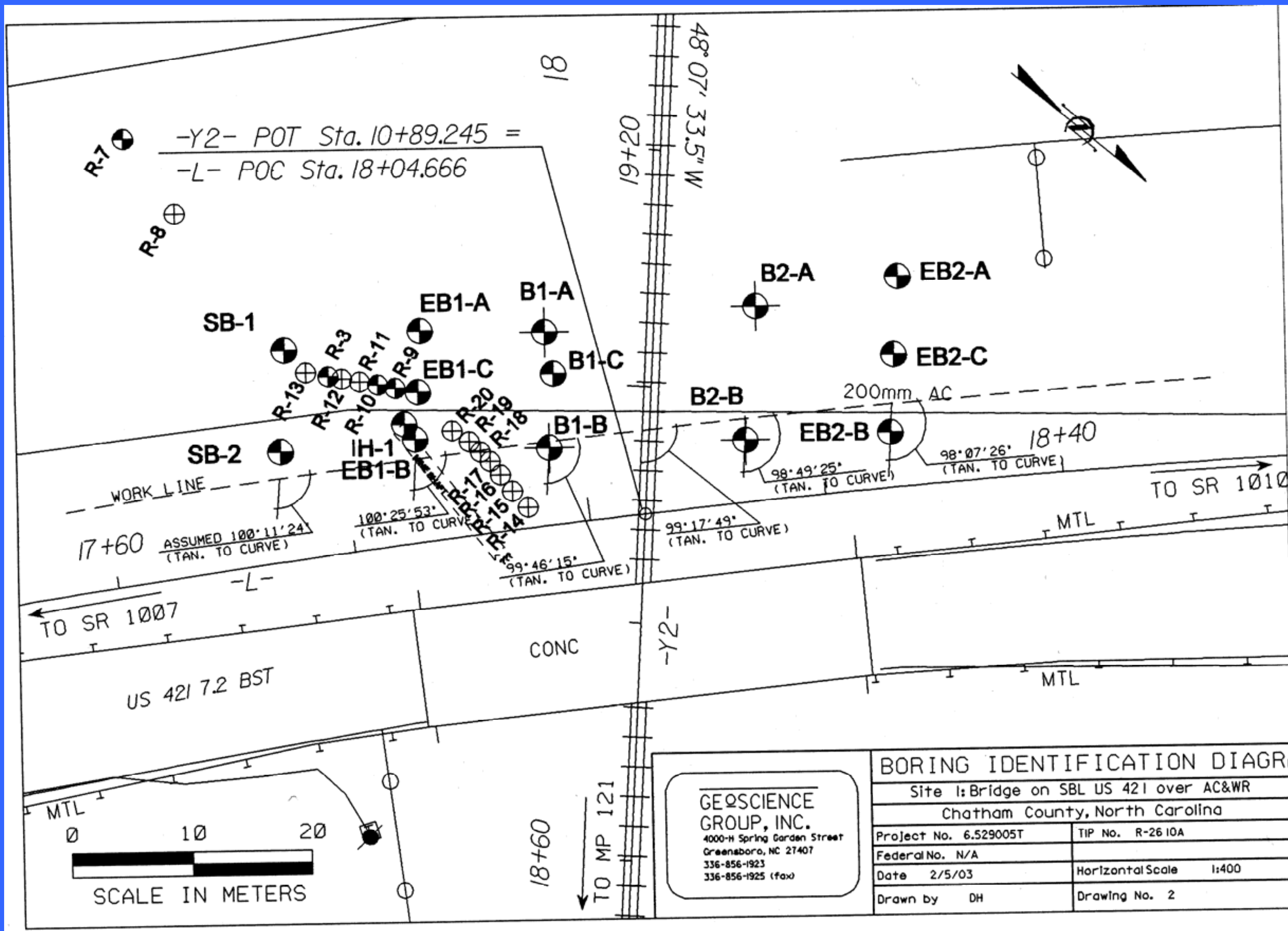
Scale 1:250

First electrode is located at 0.0 m (N-200569.1 m, E-583095.8 m)
Last electrode is located at 67.5 m (N-200619.9 m, E-583140.2 m)
2-D Least-Squares Inversion--RMS error = 3.1
Survey Coordinates: North Carolina; Datum: NAD 1983(Conus)

Results of Geophysical Investigation

- Electromagnetics gave no indication of potential tunnels
- Overall resistivity of the site was low with a range of less than 80 ohm-m
- Several higher resistivity targets identified for further investigation

Boring Investigation to confirm Geophysics



Conclusions of Boring Investigation

- Two strongest DC resistivity anomalies determined to be hard rock, not tunnels
- Twelve additional borings performed in area where tunnel previously encountered without finding any other side tunnels
- Determined that the shaft extends under the existing roadway embankment outside of area investigated

Recommendation for Site 2

- Bridge to be lengthened
- New abutment fill will be outside the known shaft location to prevent further subsidence
- Interior bent will be at shaft location with Drilled Shafts to be cased to below bottom of mineshaft

Conclusions about Geophysics at Site 2

- Geophysics did not have a chance to locate the shaft due to physical constraints limiting the test area
- Geophysical interpretations may have been influenced by the hope of success. The low resistivity across the site probably indicated a fairly uniform subsurface. The "higher" resistivity anomalies only represented harder rock, not tunnels.

Questions?